I. On the Affinity Constants and Constitution of Several Urazoles.

II. On the Velocity Constants and Mechanism of the Reactions of Alkyl Halides with Urazoles and Urazole Salts.

DISSERTATION.

SUBMITTED TO THE BOARD OF UNIVERSITY STUDIES OF THE JOHNS HOPKINS UNIVERSITY IN CONFORMITY WITH THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

BY

GUY HOWARD SHADINGER.

BALTIMORE
1907

EASTON, PA. :
ESCHENBACH PRINTING COMPANY.
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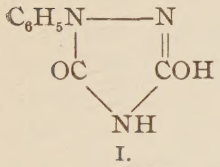
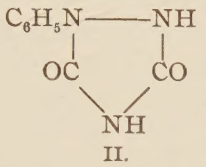
The author takes pleasure in expressing his gratitude to President Remsen, Professor Morse, Professor Jones, Professor Hulbert, Associate Professor Acree and Dr. Tingle for instruction in the lecture room and laboratory. Especial thanks are due Associate Professor Acree, under whose personal direction this investigation was made.

I. ON THE AFFINITY CONSTANTS AND CONSTITUTION OF SEVERAL URAZOLES.

Phenylurazole must have one of the five following formulas:[1]



I.



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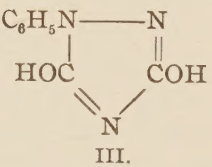
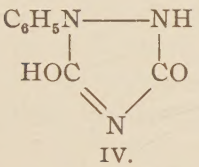
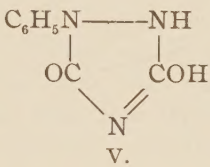


III.



IV.



V.

It has been proven that it does not exist in solution appreciably as formula V.,[2] and that it seems to react chiefly as formula I. in equilibrium with small amounts of formulas II. and III. and, perhaps, much less of formula IV.

Since both phenylurazole and phenyl-3-thiourazole form salts which, when treated with alkyl halides or alkyl sulphates, are alkylated chiefly in the 2,3 amide group, it seemed probable at the beginning of this investigation that this group is more strongly acid than the 4,5 amide group.

Since, in general, enol groups are stronger acids than keto groups, it seemed probable that the 2,3 group is present in solution largely in the enol form, and the 4,5 group chiefly in the keto form. Corroborative evidence was found in the action of diazomethane upon urazoles, thiourazoles, etc. These reactions showed that the 2,3 amide group of phenylurazole in ether solution is nearly all enol form in equilibrium with a small amount of keto form, while the 4,5 amide group is nearly

[1] Am. Chem. J., **27**, 118; **31**, 185; **32**, 606; **37**, 71, 361; **38**, 1. Ber. d. chem. Ges., **35**, 553; **36**, 3139; **37**, 184, 618.

[2] Ber. d. chem. Ges., **36**, 3139.

all keto form in equilibrium with a small amount of enol form. In each case studied, the derivatives of phenylurazole seem to behave in an entirely analogous way.

1-Phenyl-3-thiourazole, however, reacts towards diazomethane in ether solution as if the 2,3 amide group were practically completely enol in structure, and the 4,5 amide group as if it were chiefly keto derivative in equilibrium with a small amount of enol compound.

All of the 1-phenyl-2- or 3-alkylurazoles studied react as if they were nearly completely keto compounds in equilibrium with small amounts of enol derivatives. It has been clearly pointed out, however, in a former article by Acree[1] that the evidence secured by purely chemical means or by physical chemical methods is not to be considered entirely trustworthy.

Compounds having a keto structure might be comparatively strong acids, and enol derivatives might be weak acids. It is possible that such elusive tautomeric substances, even though they may exist chiefly as enol form, may react with diazomethane as if they had only the keto structure. This would happen if (1) the keto form reacts more rapidly with the diazomethane than does the enol form, (2) the keto form is in equilibrium with the enol form, and (3) the two forms change into each other very rapidly.

It is perfectly clear, then, that other evidence must be brought to bear on the problem of the constitution of these tautomeric urazoles, and the object of the work presented in this communication was to see what light the application of some of the methods of physical chemistry could throw on the subject.

If this chemical evidence is to be depended upon, a study of the conductivity of these urazoles ought to show that the 2,3 amide group is a very much stronger acid than the 4,5 amide group. The prediction has been fully verified experimentally and the results which were obtained amply confirm the validity of the conclusions drawn from the earlier evidence.

Table A.

Urazoles.	Affinity constants.
1-Phenylurazole	0.000011
1-Phenyl-4-methylurazole	0.000011
1-Phenyl-2-methylurazole	0.000000065
1-Phenyl-3-ethoxyurazole	0.000000043

[1] Acree: Am. Chem. J., 38, 1.

Table B.

Thiourazoles.	Affinity constants.
1-Phenylthiourazole	0.017
1-Phenyl-4-methylthiourazole	0.017
1-Phenyl-3-ethylthiourazole	0.00000075
1-Phenyl-3-methylthiourazole	0.00000020

In Table A. above, it is seen that the affinity constants of phenylurazole and phenyl-4-methylurazole are practically the same. This proves that, as was anticipated, most of the hydrogen and urazole ions of phenylurazole come from the 2,3 enol group and very little from the 4,5 keto group. It was, therefore, predicted that when the 2,3 amide hydrogen is replaced by a radical the affinity constant would fall to a marked extent. This idea has been amply verified, especially when hydrogen is replaced by methyl in the 2 position or by ethyl in the 3 position, the value for the affinity constants falling to about one-half of one per cent of that for phenylurazole. The methyl and ethyl radicals have about the same influence upon the 4,5 amide group.

In Table B. similar results are shown for the thiourazoles. Again the 1-phenyl-4-methyl-3-thiourazole has practically the same affinity constant as the phenyl-3-thiourazole itself. This proves that most of the hydrogen ions come from the 2,3 enol group and that the 4,5 amide (keto) group is a very weak acid. When the hydrogen of the 2,3 amide group of phenyl-3-thiourazole is replaced by the methyl or ethyl radical a marked diminution in strength is shown by the alkylurazole formed. Both radicals affect the affinity constant of the 4,5 amide group to about the same degree, as was the case with phenylurazole. It is interesting to note that by a replacement of the 3-ethoxy and 2-methyl groups by the more negative 3-thioethyl and 3-thiomethyl groups, the affinity constants become from 4 to 15 times as large.

Previous chemical work had led to the conclusion that phenyl-3-thiourazole is a much stronger acid than phenylurazole. Phenyl-3-thiourazole titrates more sharply with alkalis than does the phenylurazole and it is strong enough to color methyl orange red, whereas phenylurazole does not. A comparison

of Tables A. and B. shows that the 1-phenyl-3-thiourazole and 1-phenyl-4-methyl-3-thiourazole are 1500 times as strong as the phenylurazole and 1-phenyl-4-methylurazole. This confirmation of the purely chemical evidence by that secured by the use of physical chemical methods is very satisfactory. In order to secure conclusive evidence regarding the constitution and reaction of such tautomeric compounds both methods must be used.

During the time required to read the conductivity of these compounds there seemed to be no tautomeric changes, but, as I had already observed while studying certain alkylation reactions by means of titration methods, there was a change of phenyl-3-thiourazole and phenyl-4-methyl-3-thiourazole into the disulphides. See Tables 10 and 12 in Section I., and Table 36 in Section II.

Conductivity Apparatus.

The Kohlrausch method of measuring conductivity with a Wheatstone bridge, a telephone receiver, and an induction coil, was used. The bridge wire was made of "manganin" and was carefully calibrated. The resistance coils were standardized and found to be accurate to 0.04 per cent.

The conductivity cells were of the form used by Jones and Bingham.[1] These cells contained no material soluble in the solvent, prevented evaporation, and protected anhydrous solvents from the moisture of the atmosphere.

The electrodes were coated with platinum black, and then heated in a blast lamp until they became white. This white coating neither absorbs salts nor exerts any oxidizing action.

The sliding contact for determining the zero point was of a special form, as illustrated in Fig. I.,

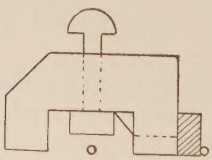


Fig 1. End View

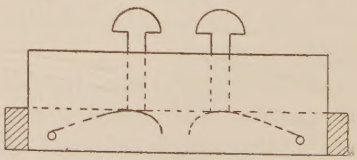


Fig I, Side View

[1] Am. Chem. J., **34**, 493.

having a double contact. The two buttons are pressed down alternately. This can be done quickly, and in this way a much more accurate reading can be made in a shorter time, as the error involved in having to remember the sound is much less than when the ordinary single contact is used.

Solvents.

Water.—The water was purified by the method of Jones and Mackay[1] and had a conductivity of from 1.8 to 2.3×10^{-6} at 25°.

Ethyl Alcohol.—The best commercial article was digested with calcium oxide and distilled through a Linnemann fractionating head. The conductivity was 2×10^{-6} at 25°.

Standard Alcoholic Hydrochloric Acid.—The alcohol prepared as above was put into a graduated flask and dry hydrochloric acid gas passed in until a slight excess over the weight required for the standard solution was obtained. The flask was filled to the mark with alcohol and the calculated amount necessary to make the solution of standard strength was then added.[2]

Bath.

The 25° bath was of the usual form, the stirrer being driven by a water motor. An Ostwald regulator was employed, but the gas channel was constricted enough to make the apparatus sensitive to 0.01°. The thermometer was standardized and graduated into tenths of a degree, but could be read easily to within 0.01°. Solutions of the urazoles in water were always made as concentrated as possible and then dilutions made as far as it was practicable to measure the conductivities.

Conductivity Measurements.

In all determinations at least three different resistances were used and the values given are the mean. The constants of the cells were checked at frequent intervals. When not in use, the cells were filled with pure water. A 0.02 normal solution

[1] Am. Chem. J., **19**, 91.
[2] Acree and Brunel: *Ibid.*, **36**, 117.

of potassium chloride was used in determining the cell constants. The conductivity of the 0.02 normal solution was taken as 129.7 at 25°. All work was done at 25°.

The μ_∞ of the Sodium Salts and of the Urazole Acids.—The $\mu\infty$ of each sodium urazole was obtained by diluting the solutions until a maximum molecular conductivity was reached. Since the sodium salts of the urazole acid esters are hydrolyzed in dilute solutions, enough of the acid ester itself was added to the solution to suppress this hydrolysis. The conductivity of the urazole acid ester in the presence of its salt is small enough to be neglected, as can be seen from Table 6.

The μ_∞ of the acids and acid esters was obtained by the use of Kohlrausch's law. This value was, on the average, about 355, which is about the same as that for other acids having nearly the same molecular weight.

The affinity constants of the urazoles were then obtained by using Ostwald's formula for the acids and acid esters and Rudolphi's formula for the sodium salts. It was shown in a former article by Acree[1] that the formula

$$\frac{H \times (C_{ki} + C_{ei})}{(C_k + C_e)} = \frac{(K_2 + K_1K_3)}{(1 + K_3)} = K$$

gives the correct affinity constant for such tautomeric urazole acids. H is the concentration, in gram molecules per liter, of the hydrogen ions, C_{ki} that of the keto anions, C_{ei} that of the enol anions, C_k that of the keto molecular form, C_e that of the enol molecular form, K_1 the affinity constant of the keto tautomer, K_2 that of the enol tautomer, and K_3 the ratio of the amount of keto molecular form to that of the enol molecular form. Since the ionic velocities of the enol and keto anions are approximately the same, the above equation assumes the form of the one used by Ostwald,

$$\frac{\alpha^2}{1 - \alpha} = \frac{\mu^2 v}{\mu_\infty (\mu_\infty - \mu_v)} = KV.$$

[1] Acree: Am. Chem. J., **38**, 12.

The same reasoning shows that the Rudolphi dilution equation holds for the salts of tautomeric acids or bases.

The above formula can be readily extended to cases in which several tautomeric forms are present, the undissociated portions of which remain in constant equilibrium and obey Ostwald's dilution law. The equation then becomes:

$$\frac{H \times (C_{kt} + C'_{kt} \text{ etc.}, + C_{ei} + C'_{et} \text{ etc.})}{(C_k + C'_k \text{ etc.}, + C_e + C'_e \text{ etc.})} = KV.$$

This formula holds perfectly well for phenylurazole, which exists in solution in at least 4 tautomeric isomers.

EXPERIMENTAL.

Phenylurazole.—This was made by the method of Acree.[1] One hundred grams of phenylhydrazine gave 100 grams of phenylurazole which, after recrystallization from alcohol, melted at 265° to 267° without decomposition. This was crystallized twice from alcohol, and water solutions were made for the conductivity measurements.

Sodium Salt of Phenylurazole.—Fifteen grams of the pure phenylurazole were heated for several hours in conductivity water in a beaker with the theoretical weight of sodium bicarbonate. Upon evaporating the solution to a small volume and cooling it, a white precipitate was formed. This was crystallized three times from distilled water and twice from conductivity water and dried in a desiccator over sulphuric acid.

The following method of analysis was followed for all sodium salts: About 0.3 gram was weighed into a platinum crucible and 3 cc. dilute sulphuric acid were added. This mixture was evaporated and the residue was ignited in a Rogers burner; the process was then repeated and the product was weighed as sodium sulphate.

Analysis:

0.2519 gram anhydrous substance gave 0.0869 gram Na_2SO_4.
6.6233 gram substance lost 1.1528 gram H_2O at 120°.

[2] Am. Chem. J., , **27**, 126.

	Calculated for $C_8H_6O_2N_3Na$.	Found.
Na	11.54	11.17

	Calculated for $C_8H_6O_2N_3Na.2H_2O$.	Found.
$2H_2O$	17.25	17.40

Table I.—Sodium 1-Phenylurazole. $\mu_\infty = 80.44$.

V.	μ_v.	α.	$K = \frac{\alpha^2}{(1-\alpha)\sqrt{v}}$.
16	57.77	0.719	0.447
32	60.04	0.747	0.388
64	62.40	0.775	0.335
128	65.05	0.809	0.302
256	67.72	0.841	0.280
512	70.00	0.870	0.258
1024	81.58	1.014	
2048	79.28	0.985	

The maximum molecular conductivity of the acid is obtained as follows: By the law of Kohlrausch $C+A = 80.44$ for the sodium salt; therefore $A = 80.44 - 49.2 = 31.24$, and the $\mu\infty$ of the acid is $31.24+325$ or 356.24.

Table II.—1-Phenylurazole. $\mu_\infty = 356.24$.

V.	μ_v.	α.	$K = \frac{\alpha^2}{(1-\alpha)}v$.
512	26.36	0.0740	0.0000115
1024	36.30	0.102	0.0000118
2048	47.77	0.134	0.0000102
4096	65.38	0.183	0.00000984
8192	82.25	0.230	0.00000946
16384	125.55	0.352	0.0000121
			$K = 0.000011$

Sodium Salt of 1-Phenyl-2-methylurazole.—Two grams of phenyl-2-methylurazole in water were treated with the the-

oretical weight of pure sodium bicarbonate and heated some hours in a beaker to expel the carbon dioxide. When the solution was evaporated to a small volume and cooled, the salt precipitated out. It was recrystallized three times from conductivity water.

Analysis:

0.2745 gram of anhydrous substance gave 0.1005 gram Na_2SO_4.

0.7227 gram substance gave 0.1445 gram H_2O at 120°.

	Calculated for $C_9H_8O_2N_3Na$.	Found.
Na	10.79	10.85

	Calculated for $C_9H_8O_2N_3Na.3H_2O$.	Found.
$3H_2O$	20.20	19.99

Table III.—Sodium 1-Phenyl-2-methylurazole. $\mu_\infty = 69.2$.

V.	μ_v.	α.	$K = \frac{\alpha^2}{(1-\alpha)\sqrt{v}}$.
64	59.07	0.8576	0.622
128	61.26	0.885	0.603
256	62.76	0.907	0.552
512	64.37	0.930	0.548
1024	66.10	0.955	0.637
2048	71.52	1.033	
Hydrolysis suppressed with molecular amount of 1-phenyl-2-methylurazole.			
2048	69.255	1.000	

The maximum molecular conductivity of the acid is obtained as follows: $C + A = 69.2$ for the sodium salt; therefore, $A = 69.2 - 49.2 = 20$, and the μ_∞ of the acid is $20 + 325$ or 345.

1-Phenyl-2-methylurazole.[1]—Twenty-four grams of phenyl-

[1] For a description of the derivatives of phenylurazole used in this work, see the article by Acree: Am. Chem. J., **38**, 1.

urazole were dissolved in a small amount of water containing one molecular proportion of sodium hydroxide. Two molecules of dimethyl sulphate, which had been shaken with alkali to remove the free acid, were added and the whole shaken one-half hour. The precipitate was recrystallized three times from distilled water, hydrolyzed with hydrochloric acid to decompose any methoxy derivative, extracted with chloroform to remove the phenylurazole, and recrystallized from conductivity water. Four grams of pure product were obtained which melted at 185°.

Table IV.—1-Phenyl-2-methylurazole. $\mu_\infty = 345$.

V.	μ_v.	α.	$K = \frac{\alpha^2}{(1-\alpha)V}$.
128	1.007	0.00291	0.0000000668
256	1.452	0.00420	0.0000000694
512	1.849	0.00535	0.0000000564
1024	2.527	0.00732	0.0000000664
2048	6.894	0.0199	(0.000000197)
4096	8.155	0.0237	(0.000000140)
			$K = 0.000000065$

Sodium Salt of 1-Phenyl-3-ethoxyuzazole.—This was prepared and purified in a manner similar to that employed for the preparation of the sodium salts spoken of above.

Analysis:

0.2999 gram of anhydrous substance gave 0.0883 gram Na_2SO_4.

	Calculated for $C_{10}H_{10}O_2N_3Na$.	Found.
Na	10.12	10.70

Table VI.—Sodium 1-Phenyl-3-ethoxyurazole. $\mu_\infty = 82$.

V.	μ_v.	α.	$K = \frac{\alpha^2}{(1-\alpha)\sqrt{V}}$.
32	59.13	0.721	0.329
64	61.96	0.755	0.292
128	64.25	0.783	0.250
256	65.22	0.795	0.193
512	67.33	0.821	0.200
1024	69.72	0.850	0.150
4096	77.18	0.941	0.235
Suppression of hydrolysis by an equal amount of 1-phenyl-3-ethoxyurazole.			
4096	82.14	1.001	
8192	81.62	0.995	

The maximum molecular conductivity of the acid is obtained as follows: $C + A = 82$ for the sodium salt; therefore $A = 82 - 49.2 = 32.8$, and the μ_∞ of the acid is $32.8 + 325$ or 357.8.

1-Phenyl-3-ethoxyurazole.—Much difficulty was experienced in obtaining this ester in large quantities by the alkylation of phenylurazole salts, and several methods were tried before a satisfactory one was found.

1. Alkylation Experiments in Ether as a Solvent.—Seventy-five grams of phenylurazole and a drop of phenolphthalein solution were titrated with a solution of potassium hydroxide. The solution was warmed and one molecular portion of silver nitrate in a little water was added with constant stirring. The silver salt was white when first formed, but soon turned dark. When washed with alcohol and ether and dried, it weighed 112 grams. Forty-five grams of this silver salt, suspended in 400 cc. of ether, and 1.5 molecules of ethyl iodide (37.5 grams) were boiled two days in a liter flask under a return condenser. The silver residue was filtered off and the ether filtrate was treated in the cold with a slight excess of dilute potassium hydroxide solution to extract the 1-phenyl-3-ethoxyurazole. This alkaline extract, when acidified with dilute sulphuric acid, gave a white precipitate of phenylurazole, 1-phenyl-3-ethoxyurazole, 1-phenyl-2-ethylurazole, and perhaps other products, and more of the ethyl esters were obtained by extracting the filtrate with ether or chloroform. Recrystal-

lization of the precipitate from a large amount of 50 per cent alcohol gave pure white, needlelike crystals which melted from 150° to 200°. When this precipitate was treated with chloroform and filtered, a small quantity of phenylurazole was left as an insoluble residue. The chloroform filtrate was evaporated and the residue was crystallized from 50 per cent alcohol. Crystals of pure 1-phenyl-3-ethoxyurazole were obtained which melted at 152° and weighed 1.2 grams. The filtrate from the 1-phenyl-3-ethoxyurazole was evaporated and it then gave 1.8 grams of crystals melting at 75° to 80°, which were probably largely 1-phenyl-2-ethylurazole. The ether solution from which the 1-phenyl-3-ethoxyurazole and 1-phenyl-2-ethylurazole were extracted retained the 1-phenyl-3,5-diethoxyurazole. The ether was evaporated off and a yellow oil was obtained which solidified on standing. This oil weighed 3.2 grams. When it was dissolved in alcohol and water was added, fine white needles were precipitated. The 1-phenyl-3,5-diethoxyurazole, when crystallized twice, as before, melted at 52°. The yield was 2.5 grams. This method was repeated twice and in both cases the same poor yields were obtained.

2. *Shaking the Silver Salt and Ethyl Iodide in Cold Ether.*—The same quantities of reagents were used as in the preceding experiment, but were shaken in a stoppered bottle three days. When the reaction product was treated as before the yield was 1.4 grams of 1-phenyl-3-ethoxyurazole (melting point 147° to 149°), 2.2 grams of low melting product (melting point 68° to 74°), and 3.6 grams of crude 1-phenyl-3,5-diethoxyurazole.

3. *Silver Phenylurazole and Pure Ethyl Iodide in the Cold.*—Ten grams of silver salt were shaken four days in a bottle with 50 grams of ethyl iodide. When the reaction product was treated as before, the yield was 0.1 gram 1-phenyl-3-ethoxyurazole, 0.5 gram low melting material (melting point 68° to 76°), and 0.7 gram crude 1-phenyl-3,5-diethoxyurazole. The yields for these three methods are about the same.

4. *Silver Phenylurazole and Pure Ethyl Iodide in Sealed Tubes.*—Fifty grams of the silver salt were put in two large Carius tubes and enough ethyl iodide (320 grams) was added to make a soft

mush. The tubes were heated two days at 50° and two days at 75°. When the reaction product was treated as before it gave 4 grams of 1-phenyl-3,5-diethoxyurazole in good condition, although it had to be crystallized first from pure alcohol. The fraction which should have been 1-phenyl-3-ethoxyurazole contained so little of this that it could not be separated from the 1-phenyl-2-ethylurazole by the ordinary methods. This fraction melted at 65° to 85°.

5. *Silver Phenylurazole and Ethyl Iodide in Ether in Sealed Tubes.*—Seventy-five grams of the silver salt were put into two tubes with two molecular proportions of ethyl iodide, and three or four times the volume of ether was then added. These two tubes were heated three days at 75°, when an accident caused the loss of one tube. The contents of the other were treated as before and gave 4 grams of 1-phenyl-3,5-diethoxyurazole in good condition, but the other product melted low, as before. This low melting material was titrated with 55 cc. of 0.1 normal sodium hydroxide solution and the urazoles were fractionally precipitated with 0.1 normal sulphuric acid. Eleven cc. of acid were used for each fraction. The first precipitate melted at 100° to 150°; the second at 80° to 125°; the third, fourth, and fifth at 72° to 95°. The first fractions were recrystallized three times from alcohol and gave 2 grams of 1-phenyl-3-ethoxyurazole, which melted at 151° to 152°. This last method seems the best of the five given.

The unchanged phenylurazole left with the silver residue can be recovered by saturating the required amount of potassium hydroxide solution with hydrogen sulphide and digesting the silver salt with the solution in the cold several hours. When the silver sulphide is filtered off and the filtrate is boiled to remove hydrogen sulphide, and acidified, the phenylurazole precipitates out in pure condition.

6. *Preparation and Hydrolysis of 1-Phenyl-3,5-diethoxyurazole.*—Thirty grams of phenylurazole were converted into disilver phenylurazole[1] by dissolving the phenylurazole in somewhat more than one molecular proportion of potassium hy-

[1] Acree: Am. Chem. J., **38**, 1; Ber. d. chem. Ges., **36**, 3146.

droxide solution, then adding nearly one molecular proportion of silver nitrate in solution, and then, alternately, solutions of potassium hydroxide and silver nitrate in separate portions until two molecular proportions of each had been used. The silver salt was prepared in a two-liter bottle which was shaken violently during the experiment. Only small quantities of the reagents should be added each time, and the bottle must be shaken *well* after each addition. The bottle was then agitated for several hours in a machine. After standing overnight, the gelatinous material was collected so that it could be filtered. It was dried in the air on porous plates. Heating, to hasten drying causes decomposition. The yield is always quantitative. The salt was then put in a flask with 500 cc. of ether and three molecular proportions of ethyl iodide and boiled three days. After filtering off the silver salts, the filtrate was extracted with potassium hydroxide solution. When the alkaline solution was acidified, it gave 1.2 grams of yellowish crystals melting at 66° to 73°.

After the ether was distilled off, the yellow oil which was left solidified. After crystallizing this solid from 95 per cent alcohol, 9.5 grams of 1-phenyl-3,5-diethoxyurazole were obtained, which melted at 52° to 53°. From the filtrate 5.2 grams of the same compound melting at 49° to 52° were obtained. It was found that, when the pure 1-phenyl-3,5-diethoxyurazole was heated in a sealed tube one hour at 85° with exactly one molecular proportion of hydrogen chloride in alcohol, the 5-ethoxy group was hydrolyzed quantitatively and pure 1-phenyl-3-ethoxyurazole was left. When the impure fraction, melting at 49° to 52°, was hydrolyzed with alcoholic hydrochloric acid, it gave 1-phenyl-3-ethoxyurazole which, after crystallization from 50 per cent alcohol, melted at 150° to 151°. This last method is the most satisfactory one used for the preparation of 1-phenyl-3-ethoxyurazole.

The sample of 1-phenyl-3-ethoxyurazole used in the conductivity measurements was recrystallized several times from pure 50 per cent alcohol.

Table VII.—1-Phenyl-3-ethoxyurazole.

$\mu_\infty = 357.8.$

$V.$	$\mu_v.$	$\alpha.$	$K=\frac{\alpha^2}{(1-\alpha)V}$
1024	2.106	0.00589	0.0000000340
2048	3.470	0.00961	0.0000000463
4096	4.451	0.0124	0.0000000382
8192	7.072	0.0198	0.0000000487
			$K = 0.000000043$

1-Phenyl-4-methylurazole.—This was made by the hydrolysis of 1-phenyl-3-ethoxy-4-methylurazole with hydrochloric acid.[1] This latter ester was made by treating 8 grams of 1-phenyl-3-ethoxyurazole with one molecular proportion of potassium hydroxide in 50 cc. of water and shaking the solution one hour with 1.5 molecular proportions of neutral dimethyl sulphate. Potassium hydroxide in solution was added from time to time to keep the solution alkaline. The product soon crystallized out. It was found that the yield is always much better if the solution is warmed before shaking. When recrystallized three times from alcohol containing a small amount of potassium hydroxide, the 1-phenyl-4-methyl-3-ethoxyurazole melted at 96°. Four grams of this ester were evaporated three times with concentrated hydrochloric acid and the residue was crystallized from alcohol. Three grams of 1-phenyl-4-methylurazole, melting at 225°, were obtained.

Table VIII. —1-Phenyl-4-methylurazole.

$\mu_\infty = 355.$

$V.$	$\mu_v.$	$\alpha.$	$K=\frac{\alpha^2}{(1-\alpha)V}$
512	26.98	0.076	0.0000122
1024	37.49	0.105	0.0000121
2048	46.76	0.132	0.0000136
4096	61.94	0.174	0.00000900
8192	74.67	0.210	(0.00000683)
			$K=0.000011$

Sodium Salt of 1-Phenyl-4-methylurazole.—This salt was made by the method used for preparing the other sodium salts.

[1] Acree: Am. Chem. J., 38, 1.

Table IX.—Sodium Salt of 1-Phenyl-4-methylurazole.

$\mu_\infty = 82.81.$

$V.$	$\mu_v.$	$\alpha.$	$K=\frac{\alpha^2}{(1-\alpha)\sqrt{V}}.$
64	55.80	0.674	0.174
128	62.19	0.751	0.200
Hydrolysis suppressed with 0.25 molecule of 1-phenyl-4-methylurazole.			
256	61.17	0.739	0.130
512	63.99	0.773	0.116
1024	63.80	0.770	0 0808
2048	68.07	0.822	0.0839
4096	71.37	0.862	0.0594
8192	82.81	1.00	

1-Phenyl-3-thiourazole.—This was made by Acree's method.[1] Ethyl 1-phenylthiosemicarbazide-1-carboxylate was extracted in a Soxhlet apparatus with alcohol and consequently the phenyl-3-thiourazole was obtained in excellent condition. For further purification it was dissolved in an excess of potassium hydroxide, heated two hours, and again precipitated by the addition of hydrochloric acid. When it was recrystallized twice from alcohol, it melted at 192° to 193°. The μ_∞ for all of the thiourazoles used in this work was assumed to be 355, which is certainly not far from the correct value. An error of even 10 conductivity units makes no appreciable error in the values of the affinity constants.

Table X.—1-Phenyl-3-thiourazole.

$\mu_\infty = 355.$

$V.$	$\mu_v.$	$\alpha.$	$K=\frac{\alpha^2}{(1-\alpha)V}.$
64	226.41	0.637	0.0175
128	271.68	0.765	0.0194
256	292.78	0.824	0.0151
Disulphide was formed very rapidly.			
512	305.96	0.861	(0.0105)
1024	295.43	0.822	(0.00403)
2048	143.30	0.403	

$K=0.017$

[1] Ber. d. chem. Ges., 36, 3151.

Sodium Salt of 1-Phenyl-3-thiourazole.—This salt was made by dissolving the theoretical weight of pure sodium bicarbonate in water, adding the 1-phenyl-3-thiourazole, and boiling the solution to expel the carbon dioxide. The solution was evaporated to dryness and the residue was heated two hours in an air bath. At the end of this time, all water of crystallization had been driven off and the weight was constant.

Table XI.—Sodium Salt of 1-Phenyl-3-thiourazole.

$\mu\infty = 77.35$.

V.	μ_v.	α.	$K = \frac{\alpha^2}{(1-\alpha)\sqrt{V}}$.
16	41.09	0.501	0.126
32	43.03	0.525	0.129
64	44.62	0.570	0.0946
128	49.09	0.599	0.0791
256	48.19	0.588	0.0525
512	50.78	0.619	0.0446
1024	64.95	0.728	0.0948
2048	58.96	0 719	0.0408
4096	67.72	0.826	0.0445
8192	77.35	1.00	

1-Phenyl-4-methyl-3-thiourazole.—This urazole derivative was made by the method suggested by Acree.[1] The 1-phenyl-4-methylthiosemicarbazide was made from phenylhydrazine and methyl mustard oil.[2] The ethyl 1-phenyl-4-methylthiosemicarbazide-1-carboxylate was made from 1-phenyl-4-methylthiosemicarbazide and ethylchlorcarbonate by Acree's method.

The reagents for making the ester were dissolved in chloroform and the solution was heated one day. When the reaction mixture was cooled, the ester which crystallized out melted at 196°. The chloroform was distilled off and the residue solidified. At first it melted slightly under 100°, but when recrystallized twice from alcohol, its melting point was 102° to 103°. This substance was not identified.

[1] Acree: Ber. d. chem. Ges., **36**, 3154.

[2] Dixon: J. Chem. Soc., **57**, 261. Busch: Ber. d. chem. Ges., **37**, 2332. Marckwald: *Ibid.*, **25**, 3107.

Table XII.—1-Phenyl-4-methyl-3-thiourazole.

$\mu\infty = 355$.

V.	μ_v.	α.	$K = \frac{\alpha^2}{(1-\alpha)V}$
256	299.72	0.844	0.0178
512	309.66	0.872	0.0116
Disulphide was formed very rapidly.			
1024	269.18	0.758	(0.00232)
2048	283.18	0.797	(0.00146)
4096	281.49	0.792	(0.000741)
8192	292.56	0.823	(0.000471)
			$K = 0.017$

1-Phenyl-3-methylthiourazole.[1]—Five grams of phenylthiourazole were neutralized with normal potassium hydroxide solution. This solution was diluted with two-thirds of its volume of alcohol and 1.15 molecular proportions of methyl iodide, and was then boiled fifteen minutes. The new material crystallized out when the solution was cooled. This ester was purified by crystallizing it from water, from alcohol containing a little methyl iodide, from absolute alcohol, and then from conductivity water. It weighed 3.5 grams and melted at 174° to 175°.

Table XIII.—1-Phenyl-3-methylthiourazole.

$\mu\infty = 355$.

V.	μ_v.	α.	$K = \frac{\alpha^2}{(1-\alpha)V}$
1024	4.02	0.0113	0.000000126
2048	5.37	0.0151	0.000000113
4096	10.06	0.0283	0.000000202
16384	25.07	0.0706	0.000000327
			$K = 0.0000002$

Sodium Salt of 1-Phenyl-3-methylthiourazole.—This was made and treated like the preceding sodium salts.

[1] Acree: Ber. d. chem. Ges., **36**, 3151.

Table XIV.—Sodium Salt of 1-Phenyl-3-methylthiourazole.

$\mu\infty = 86.95.$

$V.$	$\mu v.$	$\alpha.$	$K = \frac{\alpha^2}{(1-\alpha)\sqrt{V}}.$
64	63.63	0.731	0.249
128	70.29	0.815	0.318
256	69.07	0.794	0.191
512	73.54	0.845	0.205
1024	72.92	0.838	0.136
2048	82.04	0.943	0.348
4096	84.61	0.973	0.388
8192	86.95	.....	.....

1-Phenyl-3-ethylthiourazole.[1]—The method of preparation and purification was entirely similar to that given for 1-phenyl-3-methylthiourazole. Four grams of pure ester, melting at 137° to 138°, were obtained from 5 grams of phenylthiourazole.

Table XV.—1-Phenyl-3-ethylthiourazole.

$\mu\infty = 355.$

$V.$	$\mu v.$	$\alpha.$	$K = \frac{\alpha^2}{(1-\alpha)V}.$
2048	10.98	0.0309	0.000000483
4096	19.29	0.0943	0.000000762
16384	42.54	0.119	0.000000996
			$K = 0.00000075$

Barium Salt of 1-Phenyl-3-thiourazole.—This was made by titrating 2 grams of the 1-phenyl-3-thiourazole with the theoretical amount of standard barium hydroxide solution, evaporating the solution and drying the salt as before.

[1] Acree: Ber. d. chem. Ges., 36, 3151.

Table XVI.—Barium Salt of 1-Phenyl-3-thiourazole.

$\mu_\infty = 103.19$.

V.	μ_v.	α.	$K = \frac{\alpha^2}{(1-\alpha)\sqrt{V}}$.
64	77.04	0.746	0.274
128	87.98	0.852	0.435
256	88.52	0.857	0.323
512	93.89	0.909	0.406
1024	94.54	0.916	0.313
2048	99.80	0.935	0.318
4096	101.18	0.961	0.275
8192	103.19	....	....

1-Phenyl-3-ethoxy-4-methylurazole.—See page 138, under 1-phenyl-4-methylurazole.

On the Basic Properties of Some Urazole Esters.

In order to see if some of the urazole esters are weak bases and unite to some extent with hydrochloric acid in alcoholic solutions,[1] some conductivity measurements were made on alcoholic hydrochloric acid solutions to which varying amounts of the ester were added.

The conductivity of 0.1 normal alcoholic hydrochloric acid at 25° was found to be 21.221.[2] The data available show that the conductivity in absolute alcohol at infinite dilution of a salt having the molecular weight of those probably formed in the experiments below referred to is from one-third to one-fourth that of hydrochloric acid in equal concentration in alcohol. Therefore, the conductivity of the hydrochloride of the 1-phenyl-3-ethoxyurazole and of the other esters was taken to be one-fourth that of the 0.1 normal hydrochloric acid, or 5.302.

The total lowering of conductivity which could be produced if all the base were changed to hydrochloride would then be 21.211 — 5.302 = 15.909. The percentage of salt formed as successive amounts of base were added is found by dividing the lowering in conductivity produced by the total lowering

[1] Acree and Johnson: Am. Chem.J., **38**, 336.

[2] Wildermann: Z. physik. Chem., **14**, 231, 247. Scholl: *Ibid.*, **14**, 701. Sill: *Ibid.*, **51**, 595. Walden: *Ibid.*, **54**, 129. Godlewski: J. Chim. Phys., **3**, 393.

possible. The data do not take into consideration the small change in volume produced by adding the urazole ester. If the data were sufficiently accurate, the affinity constants of the bases could be calculated.

Table XVII.—1-Phenyl-3-ethoxyurazole in 0.1 N Alcoholic HCl.

Amount of ester added to 25 cc. 0.1 N alcoholic HCl.	μ_v.	Per cent of salt formed.
0 molecule	21.22	....
0.25 "	20.83	3.74
0.50 "	20.50	4.44
0.75 "	20.13	6.76
1.00 "	19.81	8.77
1.25 "	19.42	11.26
1.50 "	19.19	12.69
1.75 "	18.88	15.24
2.00 "	18.47	17.15

Table XVIII.—1-Phenyl-3,5-diethoxyurazole in 0.1 N Alcoholic HCl.

Amount of ester added to 25 cc. alcoholic HCl.	μ_v.	Per cent of salt formed.
0.25 molecule	20.82	2.46
0.50 "	20.46	4.71
0.75 "	20.13	6.75
1.00 "	19.81	8.77
2.00 "	18.39	17.69
3.00 "	17.24	24.94
4.00 "	16.15	31.78

Table XIX .—1-Phenyl-3-ethoxy-4-methylurazole in 0.1 N Alcoholic HCl.

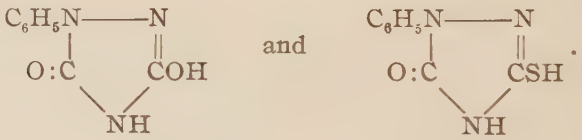
Amount of ester added to 25 cc. alcoholic HCl.	μ_v.	Per cent of salt formed.
0.25 molecule	21.04	1.04
0.50 "	20.74	2.92
1.00 "	20.13	6.75
2.00 "	19.01	13.79

Conclusions.

The affinity constant of the 2,3 amide group of phenylurazole and of 1-phenyl-4-methylurazole is 0.000011, while

that of 1-phenyl-3-thiourazole and 1-phenyl-4-methyl-3-thiourazole is about 1500 times as great, or 0.017. The affinity constant of the 4,5 amide group of the 2-alkyl and 3-alkoxy derivatives of phenylurazole is about 0.00000005, whereas the corresponding derivatives of 1-phenyl-3-thiourazole are several times as strong.

It has therefore been shown by the use of physical chemical and organic methods that those urazoles which seem to have the enol structure have much larger affinity constants than those urazoles which are apparently keto compounds. New evidence has thus been produced in favor of the view that phenylurazole and phenyl-3-thiourazole are tautomeric compounds which exist in solution chiefly in the two forms represented by the formulas



II. ON THE VELOCITY CONSTANTS AND MECHANISM OF THE REACTIONS OF ALKYL HALIDES WITH URAZOLE AND URAZOLE SALTS.

The following is a report of part of the work[1] that is being carried on in this laboratory to learn the mechanism of the alkylation reactions involved when alkyl halides, sulphates, nitrates, potassium ethyl sulphate, and similar substances react with acids, bases, and salts, such as hydroxides, carbonates, nitrates, urazoles, and many others. I am studying the problem whether acids, bases, and salts enter into these reactions through their ions or molecules, or both. I am trying to learn how alkyl halides and other alkylating agents enter into these reactions.

Do the alkyl halides dissociate, as Bruyn and Steger[2] assumed, into alkyl and halide ions which then react with other substances present?

$$KOH + C_2H_5I \rightleftharpoons \overset{+}{K} + \overset{-}{OH} + \overset{+}{C_2H_5} + \overset{-}{I} \rightarrow C_2H_5OH + \overset{+}{K} + \overset{-}{I}.$$

Do the alkyl halides unite with cations present, as Euler[3] assumed, and form complex cations which then react with other constituents of the solution?

$$KOH + C_2H_5I \rightleftharpoons \overset{+}{K} + \overset{-}{OH} + C_2H_5I \rightleftharpoons C_2H_5I.\overset{+}{K} + \overset{-}{OH} \rightarrow$$

$$\begin{cases} (1)\ \overset{+}{C_2H_5} + \overset{-}{OH} + \overset{+}{K} + \overset{-}{I} \\ \text{or} \\ (2)\ C_2H_5I.\overset{+}{K} + \overset{-}{OH} \end{cases} \searrow\nearrow\ C_2H_5OH + \overset{+}{K} + \overset{-}{I}.$$

[1] Am. Chem. J., **27**, 118; **31**, 185; **32**, 606; **37**, 71, 361; **38**, 1, 258. Ber. d. chem. Ges., **35**, 553; **36**, 3139; **37**, 184, 618.

[1] Rec. Trav. Chim., **18**, 311.

[2] Ber. d. chem. Ges., **39**, 2726.

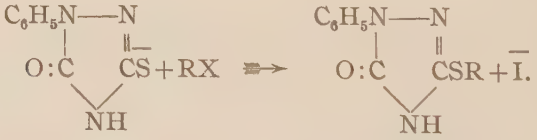
Do alkyl halides, nitrates, sulphates, hydroxides, cyanides, etc., dissociate, as Nef[1] assumed, into an unsaturated olefine or methylene derivative and the corresponding acid or water, which then react with other substances and yield the alkyl derivatives as end products?

$$C_2H_5I + KOH \rightleftharpoons C_2H_4 + \overset{+}{H} + \overset{-}{I} + \overset{+}{K} + \overset{-}{OH} \rightarrow$$
$$C_2H_4 + \overset{+}{K} + \overset{-}{I} + HOH \rightarrow C_2H_5OH + \overset{+}{K} + \overset{-}{I}.$$

Do the alkyl halides unite with the anions and form complex anions which decompose into the corresponding ester and halide ions?

$$KOH + C_2H_5I \rightleftharpoons \overset{+}{K} + \overset{-}{OH} + C_2H_5I \rightarrow$$
$$\overset{+}{K} + C_2H_5I.\overset{-}{OH} \rightarrow \overset{+}{K} + \overset{-}{I} + C_2H_5OH.$$

In the present communication the problem was attacked by studying the action of alkyl halides on urazoles and salts of urazoles, hydroxides, thioacetates, etc. A series of alkyl iodides, bromides, and chlorides was used at different concentrations to learn the effect of change in concentration, and, at different temperatures to obtain the temperature coefficients. The thiourazoles and alkyl halides do not form appreciable amounts of 2-alkylurazoles, as do the corresponding oxyurazoles,[2] but yield apparently only the 3-thioesters:



I investigated the question as to whether the anions of

[1] Ann. Chem. (Liebig), **298**, 202; **309**, 126; **310**, 316; **318**, 1, 137; **335**, 191
[2] Acree: Am, Chem. J., **37**, 71.

the urazoles, hydroxides, etc., or the undissociated substances, or both, react with the alkylating agents.

Various trials proved that the reaction goes to completion when the salt of the 1-phenyl-3-thiourazole and the alkyl halide (in slight excess) are allowed to react from two to four days. The reaction is then one of the second order, and if the anions react with the molecular alkyl halide the equation for the reaction velocity is

$$\frac{dx}{dt} = K_{trans} \times C_{anion} \times C_{alkyl\ halide} \qquad (1),$$

where K_{trans} is the reaction constant, C_{anion} is the concentration of the 1-phenyl-3-thiourazole anions, and $C_{alkyl\ halide}$ the concentration of the alkyl halide in gram molecules per liter. Under the conditions of the experiments the value of C_{anion} is always a definite fraction of the concentration of the urazole salt left in solution, and can be represented by $\alpha(A-x)$, in which α is the percentage of dissociation of the salt, A is the original concentration of the salt, and x the change in concentration of the salt. The differential equation then becomes

$$\frac{dx}{dt} = K_{trans}\,\alpha(A-x)(A-x) \text{ or } \frac{dx}{dt} = K(A-x)^2 \qquad (2)$$

when the alkyl halide and the urazole salt are originally present in the same concentration, A, and undergo the same change in concentration, x, in the time t. If the undissociated acid, base, or salt reacts with the molecular alkyl halide the equation for the reaction velocity is

$$\frac{dx}{dt} = K'_{trans} \times (I-\alpha)(A-x)(A-x) \text{ or } \frac{dx}{dt} = K'(A-x)^2 \quad (3).$$

Since in these alkylation reactions the ionized and the undissociated portions of the urazole salt are always definite

fractions of the concentration of the total urazole salt under given constant conditions, the concentration of the total salt can be substituted for the concentration of the ions or the undissociated salt in obtaining values for A, x, and $(A—x)$ in the equation $\frac{x}{t(A—x)} = AK$.

The equation therefore does not tell whether the total salt, the dissociated part, or the undissociated molecular part reacts. This question was settled by investigating the following problems:

1. The effect of adding a salt with a common ion and suppressing the ionization of the urazole salt.

2. The reaction velocity of different salts of phenylthiourazole. These different salts are dissociated to different extents and therefore have different reaction velocities.

3. The reaction velocity of the acid. This is less dissociated than the salt and so should have a smaller reaction velocity if it reacts through its ions.

The following problems also were studied:

4. The effect of change of concentration.
5. The temperature coefficient.
6. Ionization of the salts in 50 per cent alcohol.
7. How do the alkyl halides react?

8. The effect on the velocity constant produced by the change of the halogen in the alkyl halides.

9. The effect on the velocity constant produced by the change of the alkyl group in the alkyl halides.

10. Similar results in analogous reactions which are ionic.

I shall first discuss the conditions attending the reaction between sodium 1-phenyl-3-thiourazole and an alkyl halide. If we start with a solution which is 0.2 normal with respect to the sodium salt and the alkyl halide and let the reaction proceed for some time, the concentrations of the sodium salt and of the alkyl halides are constantly becoming smaller. We might at first thought expect an increase in the percentage of dissociation of the urazole salt, corresponding to such

dilution, and therefore expect an increase in the value of the velocity constant if the action is between the urazole ions and the alkyl halide, but a decrease in the value of the constant if the action is between the undissociated urazole salt and the alkyl halide. Such is not the case. Although the solution is 0.2 normal at the start, another salt, say sodium iodide, is formed, its concentration increasing as that of the sodium urazole salt decreases. The total number of gram molecules of the electrolyte present is a constant, 0.2, or the solution is always 0.2 normal with respect to the total amount of electrolyte. The work of Arrhenius,[1] Archibald,[2] and Jones[3] shows that the sodium urazole under these conditions can not change appreciably in percentage of dissociation. This follows from Arrhenius' theory that, since we have no accurate way of applying the mass law to such cases, the best way to approximate the ionization of two or more electrolytes in a solution is to assume that they share the solution between themselves in proportion to the concentration of each. For example, when half the sodium urazole is used up there is also an equal molecular amount of sodium halide formed. They then share the solvent equally and the amount of urazole left in half the solvent has the same concentration as before, 0.2 normal, and therefore is equally dissociated. This is true at any stage in the reaction, no matter what the concentration at the start.

1. As was said before, the value of the velocity constant obtained from any one set of experiments does not tell whether the action is molecular or ionic on the part of the urazole. After the addition of a certain number of molecules of sodium halide to the standard solution of sodium 1-phenyl-3-thiourazole, say 0.2 normal, the ionization of the urazole is no longer that of a 0.2 normal solution but corresponds to the new concentration which it must have in the presence of this added salt. For example, in 5 liters of solution contain 1 gram molecule of sodium 1-phenyl-3-thiourazole and 15 gram molecules of sodium iodide, the ionization of the

[1] Z. physik. Chem., **2**, 288; **31**, 206.
[2] Trans. Nov. Sco. Inst. Sci., **9**, 101.
[3] Am. Chem. J., **19**, 83; **22**, 5, 110; **25**, 349.

sodium urazole would be that of a 3.2 normal solution and not that of a 0.2 normal solution. The addition of the sodium iodide, then, causes a decrease in the ionization of the sodium urazole. If the reaction is between the urazole ions and the alkyl halide the reaction constant, expressed in the equation $\frac{dx}{dt} = K_{trans}\ \alpha(A—x)^2$, ought to decrease in direct proportion to the decrease in the percentage of dissociation of the sodium urazole. But if the action is between the undissociated molecules and the alkyl halide the reaction velocity, expressed in the equation $\frac{dx}{dt} = K'_{trans}(I—\alpha)(A—x)^2$, ough to increase with the increase in concentration of the undissociated molecular form. Of course these constants would be changed to some extent by the influence of the salts on the viscosity of the solution, by the hydration of the salts, both of which would have some effect on the velocity of the urazole ions, and *by any special catalytic action which the other salts might exert on the reaction.*

In all cases tried, a decrease in the value of the constant followed an addition of such an electrolyte to the urazole-alkyl halide solution. Apparently, then, the urazole ions react with the alkyl halide. When nonelectrolytes were added, however, there was no decrease but a slight increase, if anything, as is shown in Table II., experimental part. Electrolytes were added to solutions of sodium 1-phenyl-3-thiourazole and alkyl iodides, bromides, and chlorides, to barium 1-phenyl-3-thiourazole and ethyl iodide, to 1-phenyl-3-thiourazole and ethyl iodide, and to potassium hydroxide and ethyl iodide. *Since the constants decreased in all cases it seems that only the anions react with the alkyl halides.* See Tables II., VIII., X., XI., XII., XX., XXVII., XLI., and XLIII. in the experimental part.

Slator[1] got similar evidence that the action of sodium thiosulphate on the alkyl halides is ionic. He used ethyl bromacetate with that salt. The addition of a small quantity of silver nitrate decreased the activity of the thiosulphate

[1] J. Chem. Soc., 85, 1286; 87, 481. See also J. Chim. Phys., 4, 565; 5, 340.

because the silver nitrate rendered inactive that portion of the thiosulphate corresponding to the formation of $Na_3Ag(S_2O_3)_2$. The values of K so obtained approximated the value calculated for the sodium thiosulphate left unchanged. This result showed that the reactivity of trisodium silver thiosulphate is small compared with that of sodium thiosulphate and is negligible in the presence of a moderate excess of the latter salt.

When, however, an excess of silver nitrate was added the speed of reaction was only 0.05 of the original velocity. Slator thought that the complex salt dissociated thus:

$$Na_3Ag(S_2O_3)_2 \rightleftarrows 3\,\overset{+}{Na} + \overset{---}{Ag(S_2O_3)_2},$$

and

$$\overset{---}{Ag(S_2O_3)_2} \rightleftarrows \overset{-}{AgS_2O_3} + \overset{--}{S_2O_3}.$$

The ions $\overset{---}{Ag(S_2O_3)_2}$ and $\overset{-}{AgS_2O_3}$ and the corresponding undissociated salts either do not react at all or at least very slowly. The uncombined thiosulphate is represented by $\overset{--}{S_2O_3}$ ions, and probably the reaction depends upon their presence. Therefore, the slow activity following the addition of silver nitrate is strong evidence in support of the view that the reaction is primarily connected with the $\overset{--}{S_2O_3}$ ion.

2. If the reaction of the 1-phenyl-3-thiourazole salts is ionic and independent of the nature of the cation, various metallic salts of the 1-phenyl-3-thiourazole should give reaction constants, the values of which are directly proportional to the percentage of dissociation of those salts at the same concentration. The value of K_1 for 0.2 normal sodium phenyl-3-thiourazole and 0.2 normal ethyl iodide is 0.36. The value of K_1 for the barium salt in the same concentration is 0.32. See Tables IV., VIII., and IX. in the experimental part.

In 0.05 normal solutions sodium chloride is dissociated 87 per cent, and barium chloride 75 per cent. The velocity constants for all reactions of the sodium and barium salts of the 1-phenyl-3-thiourazole agree very well with this amount of dissociation, but the constant for magnesium 1-phenyl-3-

Temp.	Urazole.	Alkyl halide.	K_1.	
25°	Sodium 1-phenyl-3-thiourazole	Ethyl iodide	0.35	(Table V.)
25°	1-Phenyl-3-thiourazole	" "	0.192	(" XXXV.)
50°	Sodium 1-phenyl-3-thiourazole	" "	3.28	(" VI.)
50°	1-Phenyl-3-thiourazole	" "	1.568	(" XXXIII.
25°	Sodium 1-phenyl-3-thiourazole	Methyl "	7.20	(" X.)
50°	1-Phenyl-3-thiourazole	" "	18.88	(" XXXIV.)

thiourazole is apparently high. Further work is needed with these salts. The evidence obtained, however, seems to show that the urazole anions react with the alkyl halides.

3. If the reaction is ionic, the free 1-phenyl-3-thiourazole acid, in reacting with an alkyl halide, should give a much lower velocity constant than its salt in the same concentration, since organic acids are, as a rule, much less dissociated than their sodium salts. The velocity constant should be proportional to the percentage of ionization of the salt or acid if the action is ionic, but proportional to the concentrations of the molecular form if the reactions are molecular and *if the substitution of sodium for hydrogen makes no difference in the reaction velocity.* The experimental data show that the velocity constant for the acid is much lower than that for the salt. See page 34.

The velocity constants for the action of both ethyl and methyl iodides on the urazole acid decrease in value from the beginning. This is due to the formation of hydriodic acid, which suppresses the ionization of the urazole acid, and to the change of the 1-phenylthiourazole into the disulphide. The extent of the latter reaction and the value of the constant were studied in the usual manner. Since the reaction involves the ultimate union of two thiourazole anions, the formation of the disulphide must take place according to a reaction of the second order, whether the disulphide is formed directly from anions or from the undissociated thiourazole. Although a good constant was obtained for the reaction of the second order, there is no evidence on the question as to whether the anions or the undissociated thiourazole form the disulphide. This will be investigated. A 0.05 normal solution of 1-phenyl-3-thiourazole in 50 per cent alcohol gave a value of 0.0024 for K_1 (Table XXXVI.).

The evidence harmonizes completely with the assumption that the anions react with the alkyl halides.

4. The effect of change in the concentration of the reacting agents on the value of the velocity constant is now to be considered. The equation for a second order reaction shows that if the concentration becomes n times as great, the value

of the velocity constant is also n times as great. When equimolecular quantities of the two reacting materials are used the differential equation is $\frac{dx}{dt} = K(A-x)^2$. The integral of this equation is $\frac{x}{t(A-x)} = AK$, when the value of x is zero at the beginning of the reaction.

Now, if at the beginning of the reaction the concentration of the reacting substances were n times as great, the differential equation would become $\frac{dx}{dt} = K(nA-x)^2$. The integral of this equation is $\frac{x}{t(nA-x)} = nAK$ if the value of x is zero at the beginning of the reaction. The two integrals show that in the second case, in which the value of A is taken n times as great as it is in the first case, the value of the constant, nAK, is n times as large as the value of the constant AK in the first reaction. This statement does not bring into consideration the fact that a change in the percentage of dissociation accompanies a change in concentration. An increase in concentration causes a decrease in the percentage of dissociation. Therefore, when the concentration is doubled the value of the velocity constant becomes slightly less than twice the former value on account of this decrease in the dissociation. The following table gives some data bearing on this question, and the evidence is in harmony with all the other proof that the anions of the urazoles react with the alkyl halides.

Concentration of sodium 1-phenyl-3-thiourazole.	Concentration of C_2H_5I.	AK.
0.05 N	0.05 N	0.0099
0.10 N	0.10 N	0.0158
0.20 N	0.20 N	0.0361
0.40 N	0.40 N	0.0706

See Tables I., III., IV., and V. in the experimental part.

Burke and Donnan,[1] while studying the action of alkyl iodides on silver nitrate, likewise obtained changes in the

[1] J. Chem. Soc., 85, 575, 578.

value of the velocity constants with change of concentration, as is illustrated by the following table:

Initial concentration of both C_4H_9I and $AgNO_3$.	Mean velocity constant.
0.0500 N	0.00089
0.0250 N	0.00068
0.0200 N	0.00063
0.0125 N	0.00047

Initial concentration of both C_2H_5I and $AgNO_3$.	Mean velocity constant.
0.025 N	0.0022
0.0125 N	0.0015

5. A change in temperature has a great effect upon the velocity constant. Between 0° and 50° the mean temperature coefficient $(K_{t^\circ + 25^\circ}) : K_{t^\circ}$ is 10.56. For sodium 1-phenyl-3-thiourazole and C_2H_5I the value of $K_{25^\circ} : K_{0^\circ}$ is 10.75 and of $K_{50^\circ} : K_{25^\circ}$ is 10.38. The average of these two is 10.56. Arrhenius' formula,[1] $\log K_T - \log K_o = \alpha\left(\frac{1}{T_T} - \frac{1}{T_o}\right)$, gives a fair constant for α. Between 0° and 25° α is —3352. Between 0° and 50° α is —3615. Brigg's logarithms are used. For phenylthiourazole and C_2H_5I the value of $K_{50^\circ} : K_{25^\circ}$ is 8.17. See Tables I., VI., VII., XXXIII., and XXXV. in the experimental part.

It has been proven by Jones and West[2] and by A. A. Noyes[3] and Coolidge and coworkers that a change in temperature causes only a slight change in the percentage of dissociation. The increase in the reaction velocity, then, must be due to the increased velocity of the reacting particles in the solution, to the increased tendency of the particles to react when they come in contact with each other in the solution, and, without doubt, to other causes.

6. All results point to an ionic reaction on the part of the sodium 1-phenyl-3-thiourazole and the 1-phenyl-3-thiourazole, but the alkyl halides seem to react in molecular form.

Several theories have been advanced to explain the mechanism of the reactions of alkyl halides with other substances.

[1] Z. physik. Chem., **4**, 226.
[2] Am. Chem. J., **34**, 357.
[3] Z. physik. Chem., **46**, 323. J. Am. Chem. Soc., **26**, 134.

A. *The Theory of Lobry de Bruyn and Steger.*[1] These investigators supposed that in reactions between alkyl halides and other substances there is a very slight dissociation of the alkyl halide into alkyl and halide ions,

$$C_2H_5I \rightleftharpoons C_2\overset{+}{H}_5 + \overset{-}{I}$$

or

$$\frac{C_{ethyl\ ions} \times C_{iodide\ ions}}{C_{ethyl\ iodide}} = K_{ethyl\ iodide} \qquad (1),$$

and that the ions so formed then react with the ions of the other substance,

$$\overset{+}{K} + \overset{-}{OH} + C_2\overset{+}{H}_5 + \overset{-}{I} \rightarrow C_2H_5OH + \overset{+}{K} + \overset{-}{I}. \qquad (1').$$

$C_{ethyl\ iodide}$ in equation (1) should be $(C_{ethyl\ iodide} - y)$, in which y is the concentration of the ethyl and iodide ions. y is so small that it can be neglected. Since the conductivity of alkyl halides in alcohol was found to be very small indeed, it was known by Bruyn and Steger that the percentage of dissociation of the alkyl halide can be only very small at most; they supposed, however, that a small amount of dissociation really exists and could account for all of the reactions. The small conductivity shown by alkyl halides in alcohol or water may be due to a slight decomposition into a halogen acid and an alkylene group, or to other reactions, as was shown by Lengfeld[2] and Hillyer,[3] working under Remsen.

It is quite true that if the reactions of the alkyl halides do depend on the primary and instantaneous ionization of the alkyl halide, only a small amount of this ionization might be necessary to give the reaction velocities actually found by experiment. We must recall that the percentage of dissociation of many of the double cyanides, potassium silver cyanide and potassium cadmium cyanide, for example, according to the expression

$$\overset{-}{Ag}(CN)_2 \rightleftharpoons \overset{+}{Ag} + 2\overset{-}{CN},$$

[1] Rec. Trav. Chim., **18**, 325.
[2] Am. Chem. J., **11**, 40.
[3] *Ibid.*, **8**, 251.

is less than 10^{-15}. Yet when a solution of one of these double cyanides is treated with hydrogen sulphide, the precipitation of silver sulphide or cadmium sulphide is complete almost instantaneously. This shows, then, that the mechanism of the reaction assumed by Bruyn and Steger is not without analogy. There is one fact, however, that the other workers in the field have apparently overlooked, and that is that the reactions of alkyl halides do not follow the requirement of the mass law as applied to the explanation given by Bruyn and Steger.

If the reaction between ethyl iodide and sodium 1-phenyl 3-thiourazole were really a reaction between ethyl ions and urazole ions, according to the expression

$$\overset{+}{\mathrm{Na}} + \overset{-}{\mathrm{Ur}} + \overset{+}{\mathrm{C_2H_5}} + \overset{-}{\mathrm{I}} \rightarrow \overset{+}{\mathrm{Na}} + \overset{-}{\mathrm{I}} + \mathrm{UrC_2H_5} \qquad (2),$$

and if the ions are all formed practically instantaneously in comparison with the time required for the union of the ethyl and urazole ions, the velocity of the reaction would have to be expressed by the equation

$$\frac{dx}{dt} = K_{trans} \times C_{urion} \times C_{ethyl\ ion} \qquad (3).$$

In the equation (3) we can substitute $\alpha(A-x)$ for C_{urion} in which A is the original concentration of the urazole salt, x is the change in concentration of the salt in time t, and α is the constant percentage of dissociation of the salt. From equation (1) it is clear that we can substitute for $C_{ethyl\ ion}$ in equation (3) the value $K_{ethyl\ iodide} \times \frac{C_{ethyl\ iodide}-x}{C_{iodide\ ions}}$ or $K_{ethyl\ iodide} \times \frac{(A-x)}{\alpha_1 x}$, in which $K_{ethyl\ iodide}$ is the dissociation constant of the ethyl iodide, $C_{ethyl\ iodide}$ or A is the original concentration of the ethyl iodide, x is the change in the concentration of the ethyl iodide in the time t and hence is also the concentration of the sodium iodide at the time t, α is the percentage of dissociation of the sodium iodide, and $C_{iodide\ ions}$ or $\alpha_1 x$ is the concentration of the iodide ions, which come almost entirely from the sodium iodide. Equation (3) therefore becomes equation (4),

$$\frac{dx}{dt} = K_{trans} \times K_{ethyl\ iodide} \frac{\alpha(A-x)^2}{\alpha_1 x} = \frac{K(A-x)^2}{x}, \text{ or}$$

$$K = \frac{1}{t}\left(\log n \frac{A-x}{A} + \frac{x}{A-x}\right) \qquad (4),$$

if $x=0$ when $t=0$. But the application, in equation (4), of the data in Table I. in the experimental part leads to no constant value for K, and hence this interpretation of Bruyn and Steger's hypothesis is not in harmony with the experimental facts.

If we assume a very improbable case, namely, that the ethyl iodide dissociates very slowly in comparison with the union of the ethyl ions with the urazole anions, the velocity of the formation of the ethyl urazole would depend simply upon the rapidity of the ionization of the ethyl iodide. Since the velocity of the formation of the ionization products of the ethyl iodide would depend simply upon the concentration of the ethyl iodide, it follows that the velocity of formation of the ethyl urazole would be represented by the equation (5),

$$\frac{dx}{dt} = K(A-x) \text{ or } K = \frac{1}{t} \log n \frac{A}{A-x} \qquad (5),$$

in which A is the original concentration of the ethyl iodide and sodium urazole, and x is the change in concentration of the ethyl iodide or ethyl urazole in the time t. Equation (5), however, leads to no constants. It is just as improbable, further, that the entire reaction involves (1) a measurable rapidity of the ionization of the ethyl iodide, followed by (2) slow union of the ethyl and urazole anions. The equations corresponding to this case give no constants.

At the beginning of the reaction the concentration of the iodide ions is practically zero, because the ionization of the ethyl iodide can not be appreciable. But after the formation of even a small quantity of ethylurazole and sodium iodide the concentration of the iodide ions has become enormously large in comparison with the concentration of iodide ions furnished by the ethyl iodide alone. As a result of this the equilibrium of equation (1) would be disturbed, and since the C_{iodide} in equation (1) becomes very large the value of

$\frac{C_{ethyl\ ions}}{C_{ethyl\ iodide}}$ would become correspondingly smaller, and would constantly and greatly decrease during the reaction. Since the value of $\frac{C_{urion}}{C_{urazole\ salt}}$ does not change, it is evident that the value of K_{trans} in equation (3) would have to decrease enormously during the reaction. Such, however, is not the case. The value of K_{trans} has been found by many experiments to be practically a constant. It seems certain, then, that unless some further facts concerning the mechanism of the reaction are discovered in the future the hypothesis of Bruyn and Steger that alkyl halides react with other substances through primary dissociation into alkyl and halide ions, followed by the union of the alkyl ion and the anion, cannot be correct. The subject is under investigation.

B. *The bivalent-carbon hypothesis of Nef.*[1]—Nef, after exhaustive experimental work covering a period of years, came to the conclusion that alkyl halides, sulphates, nitrates, etc., alcohols, alcoholates, etc., all react with other substances only after they dissociate, to a very slight extent, into an unsaturated carbon complex and the other constituent composing the alkyl halide, sulphate, etc. There are two methods by which such a dissociation could take place; one would lead to the formation of a bivalent-carbon complex while the other would lead to the production of an olefine derivative:

$$CH_3CH_2I \rightleftharpoons CH_3CH\rightarrow + HI,$$
$$CH_3CH_2I \rightleftharpoons CH_2{=}CH_2 + HI.$$

Whether this equilibrium is between the molecular acid and the unsaturated carbon derivative as illustrated above, or between (amphoteric) ions, as illustrated in the following expressions, cannot be decided at present:

$$CH_3CH_2I \rightleftharpoons \overset{+\ -}{CH_3CH}\rightarrow + \overset{+}{H} + \overset{-}{I},$$
$$CH_3CH_2I \rightleftharpoons \overset{+}{CH_2}\text{—}\overset{-}{CH_2} + \overset{+}{H} + \overset{-}{I}.$$

[1] Ann. Chem. (Liebig) **298**, 202–374; **309**, 126; **310**, 316–335; **318**, 1–57, 137–230; **335**, 191–333.

Nef assumed that the ethylidine reacts with some other constituent, or rearranges into an olefine:

$$CH_3CH_2I + \overset{+}{K} + \overset{-}{O}C_2H_5 \rightleftharpoons CH_3CH \rightleftharpoons + \overset{+}{H} + \overset{-}{I} + \overset{+}{K} +$$

$$\overset{-}{O}C_2H_5 \rightarrow CH_3CH \rightleftharpoons + HOC_2H_5 + \overset{+}{K} + \overset{-}{I} \rightarrow CH_3CH_2OC_2H_5 +$$

$$\overset{+}{K} + \overset{-}{I}.$$

Although Nef had a large amount of experimental evidence in favor of this theory, he did not study the problem by the application of the mass law to the reactions. When this is done it is seen that there are some serious difficulties in making the facts harmonize with Nef's theory in its present form.

If Nef's latest interpretation[1] of the reactions between alkyl halides and phenylthiourazoles, for instance, were correct, and the only slow reaction were the union of the ethylidine and the urazole anion, we should have the following expressions:

$$UrH + C_2H_5I \rightleftharpoons \overset{-}{Ur} + \overset{+}{H} + CH_3CH \rightleftharpoons + \overset{+}{H} + \overset{-}{I} \rightarrow$$

$$UrC_2H_5 + \overset{+}{H} + \overset{-}{I},$$

or

$$\frac{dx}{dt} = K_{trans} \times C_{urion} \times C_{ethylidine} \qquad (1).$$

Now, at the beginning of the reaction the amount of ethylidine and of hydrogen and iodide ions is very small, at most, and could be calculated from the equation (2),

$$\frac{C_{ethylidine} \times C_H \times C_I}{C_{ethyl\ iodide}} = K_{ethyl\ iodide} \qquad (2),$$

if the value of $K_{ethyl\ iodide}$ were known. But after the formation of even a small amount of the ethylurazole and hydroiodic acid, the value of the concentration of the hydrogen and iodide ions, formed by dissociation of the hydriodic acid, becomes very large indeed in comparison with the value of the concentration of these ions furnished by the ethyl iodide alone. As a result, the value of the ratio $C_{ethylidine} : C_{ethyl\ iodide}$ must decrease correspondingly, and during the reaction

[1] See Higley: Footnote, Am. Chem. J., 37, 296.

become continuously smaller. Therefore, if Nef's theory were correct, the value of K_{trans} in equation (1) would decrease very greatly in value during the reaction. As a matter of fact it decreases only very slightly because of some secondary reactions, and, indeed, practically follows the equation

$$\frac{dx}{dt} = K_{trans} \times C_{urion} \times C_{ethyl\ iodide} \qquad (3).$$

Of course, the ratio $C_{urion} : C_{urazole}$ becomes smaller and smaller in equation (1) as the reaction proceeds, because of the suppression of the ionization of the urazole by the hydrogen ions from the hydroiodic acid formed in the reaction. Equation (3) takes this fact into consideration. Acree and his students are continuing the investigation of the mechanism of such alkylation reactions along physical chemical lines. It may be stated briefly here that I have not been able to harmonize Nef's theory with the experimental facts by assuming the following cases: (I.) A slow dissociation of the alkyl halide into an alkylidine and a halogen hydride, followed by a rapid or slow reversible or nonreversible union of the urazole ions or molecules with the alkylidine, or with the alkylidine and hydrogen ions, or with the alkylidine, hydrogen, and halide ions. (II.) An instantaneously reversible dissociation of the alkyl halide into an alkylidine and a halogen hydride followed by a fast or slow reversible or nonreversible union of the urazole ions or molecules with the alkylidine, alkylidine and hydrogen ions, or alkylidine, hydrogen, and halide ions. My own work and that of Brusoff,[1] of Conrad, Hecht, and Brückner,[2] and of others, seems to show (1) that the olefine is formed by a direct loss of a halogen acid from the alkyl halide according to a monomolecular reaction, and (2) that the ester is formed from the urazole anion and the molecular alkyl halide according to a bimolecular reaction.

It seems that all the facts known at present warrant a serious doubt as to the validity of Nef's hypothesis as it is expressed at present. It may be shown later, however, by further study of the subject that certain factors not known at present must

[1] Z. physik. Chem., **34**, .12.
[2] *Ibid.*, **4**, 273, 6319

be considered, or that a modification of Nef's view may be in harmony with the truth. This subject will be discussed in great detail in a later article. Especially must it be borne in mind, however, that in such reactions as the above the *side products*, such as olefines, may be formed by independent side reactions, and not necessarily, as Nef assumes, by a change of a methylene residue into the olefine. The olefine is not necessarily an intermediate product in the alkylation reactions.

C. *The Complex-cation Hypothesis of Euler.*[1]—Euler, in a recent article, put forward the hypothesis that alkyl halides react with other substances, such as salts, because the alkyl halide first unites to a small extent with the cation and forms a complex cation, which then reacts with the anion:

$$C_2H_5I + \overset{+}{K} + \overset{-}{OH} \rightleftarrows C_2H_5I.\overset{+}{K} + \overset{-}{OH} \rightarrow C_2H_5OH + \overset{+}{K} + \overset{-}{I} \quad (1).$$

Euler did not subject the hypothesis to quantitative proof, and this has now been done by the writer. If equation (1) represented the true course of the reaction the following analysis would hold, whether the first or second, or both, steps in reaction (1) take place with measurable rapidity: the addition of 15 molecules of potassium iodide should cause only a slight lowering of the percentage of ionization of the potassium hydroxide present, but a very large increase in the amount of the complex cations, $C_2H_5I.\overset{+}{K}$, present at any moment, and hence should *increase* very largely the velocity constant of the reaction. Such, however, is not the case. The velocity constant of the reaction between the alkyl halide and potassium hydroxide is *lowered* by the addition of potassium iodide to just about the value calculated from the suppression of the ionization of the potassium hydroxide by the potassium iodide. The same holds true for a large number of other experiments along these lines. Furthermore, reference to Tables XLV. and XLVI. shows that the addition of ethyl iodide to an alcoholic solution of sodium phenylthiourazole hardly causes any change in the conductivity of the solution. If appreciable amounts of a complex cation or anion were formed the conductivity of the solution should be lowered

[1] Ber. d. chem. Ges., 39, 2734.

considerably, since the ionic velocity of the complex cation or anion would be much less than that of the simple cation or anion. This quantitative evidence is not in harmony with Euler's hypothesis.

D. *The Complex-anion Hypothesis.*[1]—As far as the evidence goes it seems that alkyl halide molecules react with the anions of the salts which are alkylated. It may be that the alkyl halide forms a very unstable complex anion, $C_2H_5I.\overline{X}$, which at once yields halide ions and C_2H_5X. Such an assumption must be tested further, however, by experiment.

That such a hypothesis is in harmony with the qualitative and quantitative facts can be shown very readily. Conductivity and other quantitative evidence shows that at most only a very small amount of the complex anion can be present at any instant. The question then arises whether the decomposition of this small amount of complex anion can account for the reaction. The treatment of the subject now depends upon whether the formation of the complex anion from the alkyl halide and urazole anion is a reversible reaction or not.

Taking the first of these two possibilities, let us see what are the quantitative relations if the formation of the complex anion from the alkyl halide and the urazole anion is a reversible reaction. The equilibrium would be represented by the following equation, in which $C_{alkyl\ halide}$ and C_X would represent the concentrations of the alkyl halide and the anions at any moment if no complex anion were formed from them, y or $C_{companion}$ the concentration of the complex anion, and K_{equil} the equilibrium constant:

$$C_2H_5I + \overline{X} \rightleftharpoons C_2H_5I.\overline{X},$$

or

$$(C_{alkyl\ halide} - y)(C_X - y) = K_{equil}\, y = K_{equil}\, C_{companion} \quad (1).$$

If y is very small, as it is in this case, no appreciable error is involved in writing equation (1) in the form

$$C_{alkyl\ halide} \times C_X = K_{equil} C_{companion} \quad (2).$$

[1] Acree and Johnson: Am. Chem. J., 38, 262.

If, now, the complex anion yields the ester, the rate of formation of the ester must be directly proportional, at any moment, to the concentration of the complex anion, or

$$\frac{-d\,C_{companion}}{dt} = K_{trans}\,C_{companion} \qquad (3).$$

The small amount of complex anion, $-d\,C_{companion}$, changed in dt, is exactly equivalent to dx, the small amount of ester formed. If the complex anion decomposes very slowly in comparison with the rapidity of its formation, it is always practically in equilibrium with the alkyl halide and the urazole ions and we can substitute for $-d\,C_{companion}$ and $C_{companion}$ in (3) their equivalents dx and $C_{alkyl\ halide} \times C_X$. We then get

$$\frac{dx}{dt} = K_{trans} \times C_{alkyl\ halide} \times C_X \qquad (4).$$

If we started with the concentration $C'_{alkyl\ halide}$ of alkyl halide and C_{ursalt} of urazole salt at first, and x is the amount of ester which has been formed, and α is the percentage of dissociation of the urazole salt, then

$$C_{alkyl\ halide} = (C'_{alkyl\ halide} - x) \text{ and } C_X = \alpha(C_{ursalt} - x) \quad (5).$$

We can therefore substitute for $C_{alkyl\ halide}$ and C_X in equation (4) their values in equation (5), and we then get equation (6),

$$\begin{aligned} \frac{dx}{dt} &= K_{trans}\,\alpha(C'_{alkyl\ halide} - x)(C_{ursalt} - x), \\ &= K(C'_{alkyl\ halide} - x)(C_{ursalt} - x) \qquad (6), \end{aligned}$$

which is exactly the relation found experimentally.

It is clear, then, that the alkyl derivative may come from a complex anion, which has been formed in small amounts from the alkyl halide and the anion in an instantaneously reversible reaction, provided that the complex anion decomposes very slowly in comparison with the rapidity of its formation from the alkyl halide and the anion. If the equilibrium in equation (1) is established only very slowly in comparison with the rapidity of the decomposition of the complex anion into the ester and halide ions, the equations represent-

ing such a course of reactions become practically identical with those in the next case to be considered.

Another set of conditions under which the esters could be formed from a complex anion in accordance with the established quantitative data is that in which the alkyl halide and anion unite slowly in an irreversible reaction and form a complex anion which decomposes very rapidly into the ester and the halide ions. The rate of formation of the complex anion is then

$$\frac{dx}{dt} = K_{trans}\,\alpha(C_{alkyl\ halide}-x)(C_{ursalt}-x),$$
$$= K(C_{alkyl\ halide}-x)(C_{ursalt}-x) \qquad (7),$$

in which x is the concentration of the complex anion formed in the time t, $C_{alkyl\ halide}$ and C_{ursalt} the original concentrations of the alkyl halide and urazole salt, respectively, and α the percentage of dissociation of the urazole salt. But if the complex anion decomposes very rapidly, the concentration of the ester formed, y, is practically the same as x, and no measurable error is involved in substitutimg y for x in equation (7). We therefore obtain (8) for the equation expressing the velocity of formation of the ester under the above conditions. *This equation is actually found to hold experimentally.*

$$\frac{dy}{dt} = K(C_{alkyl\ halide}-y)(C_{ursalt}-y) \qquad (8).$$

These consecutive reactions can not both take place with measurable slowness; the above equations would not express the progress of the reactions. I have discussed, therefore, three sets of conditions under which a complex anion, formed by the union of an alkyl halide and an anion, could yield the alkyl derivative and a halide ion.

If the dissociation of the alkyl halides were instantaneous, we could modify the hypotheses of Bruyn and Steger and of Nef so that they would hold experimentally. But such a modification would become identical with the complex-anion hypothesis discussed above.

If the urazole ions and *both* the alkyl and halide ions, or the urazole ions and the alkylidine, hydrogen, and halide ions,

must first unite in an instantaneously reversible reaction and form a complex anion in small concentration, which then decomposes slowly according to the conditions discussed above, then the rate of formation of the ester must be expressed by the equation

$$\frac{dx}{dt} = K_{trans} \times C_{complanion},$$
$$= K_{trans} \times K \times C_{ethyl\ ion} \times C_{iodide\ ion} \times C_{urion} \quad \text{or}$$
$$K_{trans} \times K \times C_{ethyliidine} \times C_H \times C_I \times C_{urion},$$
$$= K_{trans} \times K \times C_{ethyl\ iodide} \times C_{urion},$$

which holds experimentally under all of the conditions known at present. But silver nitrate, potassium hydroxide, etc., do not react instantaneously with alkyl halides, and hence *the alkyl halides probably do not dissociate instantaneously, consequently even this modification of the hypotheses of Bruyn and Steger and of Nef does not seem to hold experimentally.*

That the alkyl halide molecules may react with the anions, however, is made probable from the fact, shown by Jones[1] and his coworkers, that neutral water forms hydrates with anions, and from the observations of Acree and Johnson[2] that acetone molecules react with hydroxylammonium ions, neutral water molecules with complex ester cations, neutral alcohol molecules with acetic acid cations, $CH_3COOH.\overset{+}{H}$, and water molecules with cane sugar cations, $(C_6H_{11}O_5)_2\overset{+}{O}H$. Acree and Nirdlinger[3] showed also that acetamide cations, $CH_3C\overset{+}{O}NH_3$, are hydrolyzed in water. All of these reactions are essentially alike.

If the alkyl halide forms an unstable compound with the anion it may be because of the unsaturated condition of the halogen of the alkyl halide or of the anion, or of both, and exactly the same reason may apply to the formation of the alkyl halide addition products of amines, dialkyl sulphides, R_2S, and other substances. That alkyl iodides react more

[1] See H. C. Jones and coworkers "Hydrates in Aqueous Solution," Publication No. 60, Carnegie Institution of Washington.

[2] Am. Chem. J., **37**, 410; **38**, 308.

[3] *Ibid.*, **38**, 489.

readily than alkyl bromides, and these more readily than alkyl chlorides, may be due to the greater tendency of the iodine to react with or absorb the anions of other groups. The fact that primary, secondary, and tertiary alkyl halides decrease in activity in the order given may be connected with the so-called space interference, as well as with the reasons discussed above. The field is a ripe one for investigation and the work outlined above will be continued.

7. Thus far all the arguments used to prove that the reaction between sodium 1-phenyl-3-thiourazole and alkyl halides is an ionic one on the part of the urazoles have been based on our knowledge of the behavior of an electrolyte in water solution. The reactions took place, however, in a 50 per cent ethyl alcohol solution, and the reaction constant is not the same as in pure water. That it is nearly the same, however, is proven by a study of the alkylation of sodium 1-phenyl-3-thiourazole by sodium chloracetate.

0.2 N sodium thiourazole + 0.2 N ClH_2COONa in water at 50°. $K_1 = 0.189$.

0.2 N sodium thiourazole + 0.2 N ClH_2COONa in 50 per cent alcohol at 50°. $K_1 = 0.15$.

See Tables XXXVII. and XXXVIII. in the experimental part.

Euler,[1] in his work on the action of chloracetic acid on silver nitrate, obtained results which were still closer.

Concentration in reaction mixture.		1000 K (80°).	
Chloracetic acid.	Silver nitrate.	Water.	45 per cent alcohol.
0.25	0.25	1.776	1.766
0.125	0.25	1.82	....
0.25	0.125	....	1.77
0.20	0.20	1.80	1.80

It is clear, then, that the fact that 50 per cent alcohol was the solvent used does not detract in the least from the validity of the evidence that the reaction is one between the urazole anions and the molecular alkyl halide.

8. When the alkyl group is the same, the velocity constant varies with the change of the halide in this order: for the

[1] *Loc. cit.*

iodide it is greater than for the bromide, and greater for the bromide, in turn, than for the chloride. This agrees with the results of other investigators whose work will be given later. The following table is a summary of the velocity constants (at 25°) of the reactions described:

Alkyl (normal).	Halide.			Ratio.		
	Iodide.	Bromide.	Chloride.	Iodine.	Bromine.	Chlorine.
CH_3	7.20	.....	.....	...	....	.....
C_2H_5	0.316	0.117	.....	1	0.37	.....
C_3H_7	0.201	0.076	0.00130	1	0.38	0.093
C_4H_9	0.214	0.074	0.00364	1	0.35	0.017

Slator[1] got similar results in the reaction of sodium thiosulphate on the monohalide acetates.

Values of velocity constants at 25°.

	Ethyl iodoacetate.	Ethyl bromacetate.	Ethyl chloracetate.
	7.00	6.40	0.06
Ratio.	Iodine.	Bromine.	Chlorine.
	1.000	0.914	0.0086

Slator[2] obtained the following ratios from the action of alkyl halides on sodium thiosulphate:

Alkyl.	Iodine.	Bromine.	Chlorine.
CH_3	1	1	0.0025
C_2H_5	1	0.62	(very small)

Menschutkin[3] got the following ratio from the action of allyl halides on organic amines:

Iodine.	Bromine.	Chlorine.
1	0.166	0.00166

It is evident, then, that my results are in harmony with those of other investigators and show beyond question that the alkyl iodides have the highest reactivity. Closely following, however, in their reactivity, come the alkyl bromides, while the alkyl chlorides lag far behind.

9. The following table shows how the values of the velocity constants, in the reactions of alkyl halides with sodium thio-

[1] J. Chem. Soc., **87**, 481.
[2] *Ibid.*, **85**, 1287.
[3] Z. physik. Chem., **6**, 52.

urazole at 25°, vary with the character of the alkyl group. Read down.

Table A.

	Halide.		
Alkyl.	Iodide.	Bromide.	Chloride.
Methyl	7.20	....	....
Ethyl	3.16	0.1170	....
n-Propyl	0.20	0.0764	0.00130
n-Butyl	0.214	0.0742	0.003640
n-Hexyl	0.0094	.....	....
n-Octyl	0.0159	.....	....
n-Cetyl	0.00132	.....	....
Isoamyl	0.0464	0.03560	0.001070
Isopropyl	0.0222	0.00626	0.000800
Isobutyl	0.0085	0.00640	0.000290
Tert. butyl	0.00088	0.00110	0.00055

The value of the constant varies greatly with the constitution in an isomeric series. In general, the secondary alkyl halide is less reactive than the primary, and the tertiary less reactive than the secondary. It will be noticed in Table B that the reactivity of the tertiary butyl iodide, bromide, and chloride does not decrease in the order given, as is generally found with the alkyl halides. In general, one must expect the relative reaction velocities of the different alkyl halides to vary with the nature of the substances with which the alkyl halides react.

Table B.

Alkyl.	Iodide.	Bromide.	Chloride.
n-Butyl	0.21400	0.07400	0.00364
Isobutyl	0.00850	0.00640	0.00029
Tert. butyl	0.00088	0.00110	0.00055

In the normal series the constant decreases with increase in the weight of the alkyl group, but the decrease is not nearly so large as that caused by the complexity of the group (side chains). Compare Tables A and B, above. It is evident that the so-called space interference may play the same rôle in these reactions that other investigators have noticed in entirely different reactions. In order to show the general relations, a resumé of some of the more important researches

dealing with, or showing, the so-called space interference is made in this section.

Wislicenus[1] studied the action of alkyl iodides on ethyl sodium acetoacetate in ethyl alcoholic solution and obtained the following results:

Table C.

Iodide.	Relative velocity.
Methyl	196
Ethyl	21
n-Propyl	5
Isopropyl	1–9
Tert. butyl	(very small)
Allyl	784+

Menschutkin[2] obtained the following results with triethylamine in acetone solution at 100°:

Table D.

Iodide.	Relative velocity.	Iodide.	Relative velocity.
Methyl	1140.00	*n*-Butyl	1.38
Ethyl	10.10	*n*-Heptyl	1.08
n-Propyl	1.93	*n*-Octyl	1.00

Menschutkin also obtained the following results in his work on triethylamine and alkyl halides in acetone solutions:

Table E.

Alkyl.	Iodide.	Bromide.	Alkyl.	Iodide.
Ethyl	0.0608	0.00958	*n*-Butyl	0.00832
n-Propyl	0.0116	0.00165	Isobutyl	0.00191
n-Butyl	0.0083	0.00123	*n*-Propyl	0.0116
n-Heptyl	0.0065	0.00119	Isopropyl	0.00121
n-Octyl	0.0060	0.00110		

Hecht, Conrad, and Brückner[3] worked with alkyl iodides and sodium ethoxide in ethyl alcoholic solution at 30°, and obtained the following results:

Table F.

Iodide.	Relative velocity.	Iodide.	Relative velocity.
Methyl	61.72	Isopropyl	0.92
Ethyl	4.87	*n*-Heptyl	1.04
n-Propyl	1.71	*n*-Octyl	1.00

[1] Ann. Chem. (Liebig), **212**, 239.
[2] Z. physik. Chem., **5**, 589.
[3] *Ibid.*, **4**, 273, 631.

Burke and Donnan[1] worked with alkyl iodides and silver nitrate and found the relative reaction velocities to decrease in the following order: isopropyl, ethyl, *n*-propyl, methyl, *n*-butyl, isoamyl, isobutyl.

Slator[2] studided the action of sodium thiosulphate on the esters of monohalogen substitution products of acetic acid.

Table G.

Halide substitution product.	Relative velocity.
Ethyl iodoacetate	118.64
Ethyl bromacetate	108.47
Methyl bromacetate	99.15
Ethyl chloracetate	1.017
Methyl chloracetate	1.00

Menschutkin,[3] in his work on the influence of chemical constitution on the speed of esterification, has obtained results which, in general, are analogous:

Table H.

Primary alcohols.	Initial velocity.	Relative velocity.	Limit of esterification.
Methyl	55.60	.....	67.52
Ethyl	46.95	70.52	66.57
Propyl	46.92	70.18	66.85
Butyl	46.85	69.61	67.30
Octyl	46.59	64.40	72.34
Isobutyl	42.36	66.66	67.38

Acids with primary radicals.

Table I.

Acid.	Initial velocity.	Limit of esterification.
Formic	61.69	64.23 at 100°
Acetic	44.36	67.36 at 155°
Propionic	41.18	68.70 at 155°
n-Butyric	33.25	69.52 at 155°
n-Caproic	33.08	69.81 at 155°
n-Caprylic	30.86	70.87 at 155°

From the above work the following conclusions were drawn by Menschutkin:

[1] J. Chem. Soc., **85**, 555.

[2] *Ibid.*, **87**, 481.

[3] Ann. Chem. (Liebig), **195**, 334; **197**, 193. Ann. Chim. Phys., [5], **23**, 14. Ber. d. chem. Ges., **10**, 1728; **11**, 679, 1507, 2117, 2148. Compt. rend., **105**, 1016.

(1) "The primary alcohols possess the highest limit of esterification and the greatest initial velocity. In the series given in Table H the velocity and limit vary regularly with the molecular weight."

(2) "The initial velocity and limit of the secondary alcohols are less than the primary alcohols; analogous differences in composition correspond with analogous differences of esterification."

(3) "The velocity and limit of the tertiary alcohols are very small, and they decompose during esterification."

(4) "The primary monobasic acids possess the smallest limit of esterification and the highest initial velocity. In the series given in Table I the limit and velocity vary regularly with the molecular weight of the acid."

(5) "The secondary acids show smaller initial velocities but higher limits of esterification than the primary acids; the effect of variation of composition is not marked."

(6) "The tertiary monobasic acids, whether of the fatty or aromatic series, are characterized by the smallest velocity, but by the highest limit of esterification."

Esterification of Aromatic Acids.

This work was done by Victor Meyer[1] with Fischer's method for esterification. The work, in general, gave valuable results as to the influence of chemical constitution on the speed of reaction, and they agree with the others given above. The conclusions which bear on my work on the urazoles was summed up as follows:

The speed of esterification is diversely influenced by substituting groups or elements of different relative mass. Symmetrical trisubstituted carboxylic acids are not esterified unless the carboxyl group is joined by one or more carbon atoms to the benzene nucleus. Symmetrical trichlor-, tribrom-, and trinitro-, and 2,6-dibrombenzoic acid are not esterified; thymolic, 2,6-hydroxyphenylbenzoic, and mesitylenecarboxylic acids are esterified.

Heating causes an increased action in some cases. Those

[1] Meyer and Sudborough: Ber. d. chem. Ges., **27**, 510, 1580, 3146. Meyer: *Ibid.*, **28**, 182, 1254, 2773, 3197; **29**, 830, 839, 1397. Z. physik. Chem., **24**, 219.

radicals which prevent a reaction at high temperatures have a much greater relative mass than those which hinder action at lower temperature.

The groups OH, CH_3, and F in the two ortho positions retard the formation of ethereal salts, while Cl, Br, I, and NO_2 prevent it altogether.

When working with isomeric compounds, those containing substituting groups in the meta position are perhaps most readily acted upon, the para compounds nearly to the same extent as the meta, and the ortho compounds least. Results obtained by Kellas[1] agree with this last statement, as shown by the following table:

Table J.

	Relative velocity.					
Position.	Cl.	Br.	I.	NO_2.	CH_3.	OH.
Ortho	35.7	7.0	9.3	4.2	28.4	15.3
Meta	55.2	18.4	28.3	22.3	63.8	55.9
Para	53.1	17.2	26.8	22.3	71.0	51.3

The order of the reaction velocity for ortho acids is as follows: Benzoic, chlorbenzoic, toluic, brombenzoic, iodobenzoic, nitrobenzoic; but toluic comes before chlorbenzoic for the meta and para acids, and nitro before iodo for meta acids. Therefore the effect of the molecular weight is only comparable for analogous compounds. In hydrolysis the velocity is least for ortho acids.

Brussoff[2] worked with 2-normal potassium hydroxide and alkyl iodides in 96 per cent alcohol at 78°. The following table shows the relative maximum velocity of the evolution of the corresponding olefine.

Table K.

Iodide.	Relative maximum velocity.
Ethyl	1.66
Propyl	2.24
Isopropyl	2.86
n-Butyl	1.00
Isobutyl	2.84
Secondary butyl	5.06
Tertiary butyl	8.00

[1] Z. physik. Chem., **24**, 221.
[2] *Ibid.*, **34**, 129.

(1) "This shows that the mechanism of the reaction is different from that of the preceding work. The work shows that the velocity of the formation of the olefine is greatest from the iodides, from the bromides it is less, and it is smallest from the chlorides."

(2) "A change of solution from ethyl to methyl alcohol, or a change of alkali from potassium hydroxide to sodium hydroxide, has little effect on the velocity of formation of the olefine."

(3) "The amount of olefine formed, as well as the velocity of its formation, depends but little upon the primary, secondary, or tertiary constitution of the carbon chain, but primarily upon the number of side chains and their proximity to the side chain containing the halogen atom."

My work, then, on the action of various alkyl halides on the salts of urazoles shows that the same stereochemical relations are involved in these alkylation reactions as were discovered in the various reactions discussed above.

10. *Results Similar to those Described in the Urazole Work.*

(1) *The speed of reaction of sodium 1-phenyl-3-thiourazole on sodium monochloracetate* was studied, both in water solution and in 50 per cent alcohol solution. All solutions were 0.2 N and the temperature was 50°. The value of K_1 in water solution was 0.189, while in 50 per cent alcohol solution K_1 was 0.150. See Tables XXXVII. and XXXVIII. in the experimental part. The sodium chloracetate was made by titrating a boiling solution of sodium bicarbonate, 20 cc. N solution, with chloracetic acid in the presence of phenolphthalein. The solution was then made up to 100 cc.

(2) *The action of sodium thioacetate on ethyl iodide* was investigated. The solutions used were 0.2 N, and the temperature was 25°. The sodium thioacetate was made by titrating 20 cc. of N sodium hydroxide with a water solution of thioacetic acid until the red color of phenolphthalein disappeared. The solution was then made up to 100 cc. The value of K_1 was found to be 0.40. See Table XXXIX. in the experimental part.

(3) *Action of N potassium hydroxide upon N ethyl iodide.*—It was suspected that when the alkyl halides react with alkali hydroxides, the reaction is really between the molecular alkyl halide and the hydroxyl ions. The following equation was found to express approximately the course of the reaction:

$$\frac{dx}{dt} = K_{trans}\,\alpha(A - x)(A - x) = K(A - x)^2 \qquad (1).$$

K_{trans} is the velocity constant, α the percentage of dissociation of the potassium hydroxide, A the original concentration of both the alkyl halide and the potassium hydroxide, and x the change in concentration of these two substances in the time t. If equation (1) expresses the reaction it is evident that the addition of potassium iodide should lower the value of α, and hence of K_1, *unless the potassium iodide has a large positive catalyzing effect.* In my work, since the data are lacking, α was assumed to be the same in 50 per cent alcohol as in water, and the formation of potassium alcoholate was left out of account. Since the potassium hydroxide and potassium alcoholate both react with the alkyl halide in independent side reaction, and since α is used only for comparison, the error involved in the assumptions is not large, but can well account for the difference between the theoretical and observed values of K_1.

$A\,K$ in Table XL. was found to be 0.011, while in the presence of 5 molecular portions of potassium iodide the value of $A\,K$ was lowered to 0.00614 instead of the calculated value 0.0082. The values of μ_v in 0.5 N and 3 N solutions were assumed to be 184 and 137.

The N potassium hydroxide solution was made by neutralizing barium hydroxide with potassium sulphate. The resulting solution was evaporated to a small volume in platinum dishes. The carbonate formed during evaporation was precipitated with barium hydroxide and the solution was then made normal by titrating it against N sulphuric acid and diluting it properly. K_1 was found to be 0.022. When the action was suppressed with 5 molecular portions of potas-

sium iodide K_1 was lowered to 0.0123. See Tables XL. and XLI. in the experimental part.

(4) *Action of N potassium hydroxide upon N methyl iodide.* K_1 was found to be 0.178. When suppressed as before, K_1 was 0.085. The value of K_1 fell with considerable regularity, due to hydrolysis of the methyl iodide in 50 per cent alcoholic solution. To study the velocity of this hydrolysis a 0.5 N solution in 50 per cent alcohol, which has the same concentration as the reaction mixture above, was made and the velocity of the reaction was then determined as usual. The value of the concentration of the water hardly changes, and the methyl iodide is the only substance appreciably diminishing in concentration. The hydrolysis of the methyl iodide should follow approximately the equation for a reaction of the first order during the first part of the reaction, before the reverse reaction is appreciable. K was found to be 0.00023. See Tables XLII., XLIII., and XLIV., in the experimental part.

The reactions between potassium hydroxide and alkyl halides furnish excellent proof that, just as with the urazoles, the hydroxyl anion reacts with the molecular alkyl halide.

$$\overline{OH} + C_2H_5I \rightleftharpoons C_2H_5I.\overline{OH} \rightarrow \overline{I} + C_2H_5OH.$$

EXPERIMENTAL.

The 1-phenyl-3-thiourazole was prepared according to the method described by Acree.[1] The ethyl 1-phenylthiosemicarbazide-1-carboxylate was purified by extraction in a Soxhlet apparatus with alcohol, and crystallization. It melted at 221°. By this method a pure 1-phenyl-3-thiourazole, m. p. 192°–193°, was obtained.

The sodium 1-phenyl-3-thiourazole was made by weighing out a quantity of the phenyl-3-thiourazole and titrating this with the theoretical amount of purified and dried sodium bicarbonate in solution. The solution was evaporated to dryness, heated to constant weight, and placed in a desiccator. To make solutions of the required normality from this salt, the theoretical weight was dissolved in water and diluted to

[1] Ber. d. chem. Ges., 36, 3151.

the required volume. The alkyl halides were made by Kahlbaum and were redistilled before use.

Unless otherwise stated, all alkyl halide solutions were made in absolute alcohol as follows: A measuring flask was nearly filled with absolute alcohol and weighed. Then a slight excess of the alkyl halide (the volume was calculated from its specific gravity) was measured into the flask, which was then weighed a second time. The flask was then kept in the thermostat until a temperature of 25° was reached, and it was then filled to the mark. The amount of absolute alcohol necessary to dilute the alkyl halide solution to the proper strength was then added. These solutions of sodium salt and alkyl halide were kept in a bath at 25°. Ten cc. portions of each were then measured into test tubes by means of carefully graduated pipettes; the concentrations at the top of each table in the experimental part refer to the separate solutions before they were mixed. The urazole solution was measured in first, because the evaporation from the water solution was slight. Then the solution of alkyl halide was added, the point of the pipette being kept below the liquid in the test tube to prevent evaporation. The test tubes were then tightly corked, and, after various time intervals, were quickly poured into 200 cc. of water, containing 4 cc. of starch solution. This resulting solution was then quickly titrated with a standard iodine solution. The alkylation reaction was, of course, nearly stopped by the large dilution with water.

The bath was the one used in the conductivity measurements. The water was kept well stirred with a water motor and propeller and the temperature was carefully regulated.

The error in titration was slight, as it was found that sodium 1-phenyl-3-thiourazole titrates with iodine as sharply as does a thiosulphate.

The error due to the hydrolysis or decomposition of the alkyl halide, especially the secondary and tertiary alkyl halides, in the water solution was noticeable. This tended to reduce the speed of the alkylation and so lowered the constant. See Table XLIV., and also the note to Table XL.

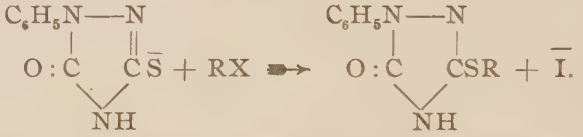
A third error was introduced by the formation of 1-phenyl-3-thiourazole through the hydrolysis of the sodium 1-phenyl-

3-thiourazole by water, and through the liberation of the urazole acid from the salt by the halogen acid formed by decomposition of the alkyl halide. The phenyl-3-thiourazole is more slowly alkylated than the sodium salt. This tends to lower the constant.

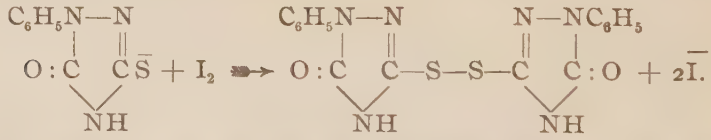
A fourth error could arise from the reaction of the sodium hydroxide, formed by the hydrolysis of the sodium phenyl-3-thiourazole, with the alkyl halide. By this reaction the concentration of the alkyl halide, and consequently the value of the constant, is lowered.

The error due to the volatilization of the alkyl halide was carefully guarded against, but must be appreciable. Rubber stoppers were used in the test tubes when the experiments were performed at 50°.

The reaction of the alkyl halides on the sodium thiourazole proceeds as follows:



The action of iodine on the sodium 1-phenyl-3-thiourazole is the following:



In obtaining the data for the following tables all of the values are expressed in terms of cc. of standard iodine solution; these are directly proportional to cc. of standard solution, and therefore weights, of sodium 1-phenyl-3-thiourazole (or acid). A is the original amount of sodium 1-phenylthiourazole taken for each titration, x is the amount changed in time t, and $A-x$ is the unchanged urazole salt (or acid). I assumed that the alkyl halides react only with the ions of the sodium 1-phenyl-3-thiourazole (or acid), and are not appreciably hydrolyzed or decomposed. Then A, x, and $A-x$ can

also represent the corresponding values of the alkyl halides. t is expressed in minutes.

The values for the amounts of the phenylalkylthiourazole formed could also be used. A could be calculated theoretically from the original concentration of sodium 1-phenyl-3-thiourazole, or the alkyl derivative formed could be separated and weighed after each experiment is complete. Both of these methods have been used in previous work by Acree,[1] Brunel, and Johnson. A and x would then represent the amount of phenylalkylthiourazole formed after time t.

The values of A_1K_1 and K_1 given with each table are calculated on the basis that A is some multiple of 10 cc., and K_1 is the value of the velocity constant when the concentration is 1 gram molecule per liter. K_1 should be, and is, nearly independent of the concentration because the percentage of ionization of the salt changes very little with the change in concentration employed in these experiments. The solvent was 50 per cent alcohol unless otherwise stated. The concentrations given at the head of each table are those of the individual solutions before they were mixed.

Table I.

25°. 0.1 N sodium 1-phenyl-3-thiourazole +0.1 N C_2H_5I.

t.	A.	$A-x$.	x.	AK.
35	10.95	6.81	4.14	0.0174
60	10.95	5.42	5.53	0.0170
120	10.95	3.58	7.37	0.0172
240	10.95	2.20	8.75	0.0166

Average, 0.0173

$A_1K_1 = 0.0158$ and $K_1 = 0.316$

The effect of various organic and inorganic substances on the velocity constant of the reaction between 0.1 N sodium 1-phenyl-3-thiourazole and 0.1 N C_2H_5I was studied.

[1] Am. Chem. J., **37**, 71.

Table II.

.	*A.*	*A—x.*	*x.*	*AK.*			
120	10.95	3.80	7.15	0.0156	3 mols	NaCl	(0.1754 grams)
120[1]	10.95	4.11	6.84	0.0138	3 "	$NaNO_3$	(0.2551 ")
120[2]	10.86	4.50	6.37	0.0118	3 "	KNO_3	(0.3035 ")
120	10.86	4.80	7.06	0.0154	3 "	Na_2SO_4	(0.4262 ")
120	10.86	3.70	7.16	0.0161	3 "	$NaI.2H_2O$	(0.5516 ")
120	10.86	4.00	6.86	0.0150	10 "	NaI	(1.4986 ")
120	10.86	4.26	6.62	0.0130	15 "	NaI	(2.2479 ")
120	10.86	4.96	6.90	0.0145	15 "	KBr	(1.7866 ")
120	10.86	3.98	6.88	0.0144	15 "	NaBr	(1.5445 ")
120	10.86	4.27	6.58	0.0128	15 "	$BaCl_2.2H_2O$	(3.3947 ")
120	10.86	3.36	7.50	0.0186	20 "	urea	(1.2012 ")
120	10.86	3.54	7.32	0.01715	10 "	cane sugar	(3.4218 ")
+120	10.86	3.54	7.32	0.01715	10 "	" "	(3.4218 ")
120	10.86	3.38	7.48	0.0184	15 "	glucose	(2.7014 ")
120	10.86	3.35	7.51	0.0186	10 "	mannite	(1.8211 ")

[1] The very great suppression caused by sodium nitrate and potassium nitrate may be explained by assuming that these salts react with ethyl iodide and form ethyl nitrate. This, in turn, may be hydrolyzed and form nitric acid or may react with sodium 1-phenyl-3-thiourazole and give 1-phenyl-3-ethylthiourazole. This nitric acid would react with the sodium 1-phenyl-3-thiourazole and form phenyl-3-thiourazole, which would be alkylated much more slowly than the sodium 1-phenyl-3-thiourazole. All of these changes would tend to aid the suppression of the value of the constant.

[2] This experiment was repeated and gave identical results,

Table III.

25°. 0.05 N Sodium 1-phenyl-3-thiourazole +0.05 N C_2H_5I

t.	*A.*	*A—x.*	*x.*	*AK.*
30	4.72	3.65	1.07	0.00977
60	4.72	3.02	1.70	0.00938
180	4.72	1.795	2.925	0.00905
310	4.72	1.09	3.63	0.00922

Average, 0.00935

A_1K_1 = 0.00991 and K_1 = 0.396

Table IV.

25°. 0.2 N Sodium 1-phenyl-3-thiourazole +0.2 N C_2H_5I.

t.	*A.*	*A—x.*	*x.*	*AK.*
15	18.88	12.29	6.59	0.0357
32	18.88	8.90	9.98	0.0350
60	18.88	6.00	12.88	0.0357
120	18.88	3.43	15.45	0.0375

Average, 0.0359

A_1K_1 = 0.0361 and K_1 = 0.361

Table V.

25°. 0.4 N Sodium 1-phenyl-3-thiourazole +0.4 N C_2H_5I.

t.	*A.*	*A—x.*	*x.*	*AK.*
15	37.76	19.00	18.76	0.0658
30	37.76	12.80	24.96	0.0650
45	37.76	9.47	28.29	0.0663
60	37.76	7.20	30.475	0.0697

Average, 0.0667

A_1K_1 = 0.0706 and K_1 = 0.352

The average value for K_1 in Tables I., III., IV., and V. is 0.36.

Table VI.

50°. 0.1 N Sodium 1-phenyl-3-thiourazole +0.1 N C_2H_5I.

t.	*A.*	*A—x.*	*x.*	*AK.*
10	9.44	3.80	5.64	0.148
20	9.44	2.26	7.18	0.159
40	9.44	1.30	8.14	0.156
81	9.44	0.70	8.74	0.154
190	9.44	0.30	9.14	0.160

Average, 0.155

A_1K_1 = 0.164 and K_1 = 3.28

Table VII.

0°. 0.1 N Sodium 1-phenyl-3-thiourazole + 0.1 N C_2H_5I.

t.	*A.*	*A*—*x.*	*x.*	*AK.*
30	10.86	10.03	0.83	(0.00275)
60	10.86	9.70	1.16	0.00191
120	10.86	9.06	1.80	0.00168
563	10.86	6.09	4.77	0.00139
1080	10.86	4.28	6.58	0.00142

Average, 0.00160

A_1K_1 = 0.00147 and K_1 = 0.029

Table VIII.

25°. 0.2 N Barium 1-phenyl-3-thiourazole + 0.2 N C_2H_5I.

t.	*A.*	*A*—*x.*	*x.*	*AK.*
15	19.80	13.55	6.25	0.0307
30	19.80	10.00	9.80	0.0326
60	19.80	6.86	12.94	0.0316
120	19.80	4.10	15.70	0.0319

Average, 0.0317

A_1K_1 = 0.032 and K_1 = 0.32

15 mols. $BaCl_2.2H_2O$ (6.4070 grams) added.

128	19.80	7.25	12.55	0.0135

After standing two days in the cold and one day at 75° only half a drop of iodine was required for the titration, so the reaction was complete.

Table IX.

25°. 0.2 N Magnesium 1-phenyl-3-thiourazole + 0.2 N C_2H_5I.

t.	*A.*	*A*—*x.*	*x.*	*AK.*
15	16.908	11.15	5.758	0.0344
30	16.908	8.14	8.768	0.0359
60	16.908	5.20	11.708	0.0375
120	16.908	2.70	14.208	(0.0438)

Average, 0.0359

A_1K_1 = 0.0425 and K_1 = 0.425

Table X.

25°. 0.1 N Sodium 1-phenyl-3-thiourazole +0.1 N CH_3I.

t.	*A.*	*A—x.*	*x.*	*AK.*
5	10.86	3.50	7.36	0.420
10	10.86	2.30	8.56	0.371
20	10.86	1.33	9.53	0.358
30	10.86	0.78	10.08	0.416
60	10.86	0.56	10.30	(0.306)
120	10.86	0.67	10.19	(0.126)
			Average,	0.391

$A_1K_1 = 0.360$ and $K_1 = 7.20$

5 mols. NaI (0.7493 gram) added.

120	10.86	2.81	8.05	0.0238

Table XI.

25°. 0.1 N Sodium 1-phenyl-3-thiourazole + 0.1 N *n*-propyl iodide.

t.	*A.*	*A—x.*	*x.*	*AK.*
30	10.86	8.09	2.77	0.0114
60	10.86	6.60	4.26	0.0107
120	10.86	4.70	6.10	0.0107
240	10.86	3.00	7.86	0.0109
			Average,	0.0109

$A_1K_1 = 0.010$ and $K_1 = 0.20$

5 mols. NaI (0.7493 gram) added.

120	10.86	5.19	5.67	0.0091

Table XII.

25°. 0.1 N Sodium 1-phenyl-3-thiourazole + 0.1 N isopropyl iodide.

t.	*A.*	*A—x.*	*x.*	*AK.*
30	10.86	10.24	0.62	(0.00203)
60	10.86	10.07	0.79	0.00137
120	10.86	9.54	1.32	0.00115
240	10.86	8.60	2.26	0.00109
			Average,	0.0012

$A_1K_1 = 0.0011$ and $K_1 = 0.022$

5 mols. NaI (0.7493 gram) added.

120	10.86	9.70	1.16	0.000997

Table XIII.

25°. 0.1 N Sodium 1-phenyl-3-thiourazole + 0.1 N *n*-butyl iodide.

t.	*A.*	*A*—*x.*	*x.*	*AK.*
30	10.86	7.95	2.91	0.0122
60	10.86	6.50	4.36	0.0112
120	10.86	4.565	6.295	0.0115
240	10.86	2.90	7.96	0.0114
			Average,	0.0116

$A_1K_1 = 0.0107$ and $K_1 = 0.214$

Table XIV.

25°. 0.2 N Sodium 1-phenyl-3-thiourazole + 0.2 N isobutyl iodide.

t.	*A.*	*A*—*x.*	*x.*	*AK.*
240	19.00	15.30	3.70	0.001004
480	19.00	13.57	5.43	0.000833
1320	19.00	9.78	9.22	0.000714
			Average,	0.00080

$A_1K_1 = 0.00085$ and $K_1 = 0.0085$

Table XV.

25°. 0.2 N Sodium 1-phenyl-3-thiourazole + 0.2 N ter. butyl iodide.

t.	*A.*	*A*—*x.*	*x.*	*AK.*
30	21.76	21.14	0.62	(0.000977)
240	19.00	18.40	0.60	0.000136
480	19.00	18.30	0.70	0.0000795
1320	19.00	18.11	0.89	0.0000372
			Average,	0.0000842

$A_1K_1 = 0.0000886$ and $K_1 = 0.00088$

Table XVI.

For this table and the three following this formula was used: $(A - B)K = \frac{1}{t} \log \frac{B(A - x)}{A(B - x)}$.

25°. 0.2 N Sodium 1-phenyl-3-thiourazole + 0.066 N *n*-hexyl iodide.

t.	*A.*	*A—x.*	*x.*	*B—x.*	*B.*	*(A—B)K.*
30	19.00	18.49	0.51	5.82	6.33	(0.000822)
240	19.00	16.59	2.41	3.92	6.33	0.000621
420	19.00	15.60	3.40	2.93	6.33	0.000592
1320	19.00	13.43	5.57	0.76	6.33	0.000582

Average, 0.000601
$(A_1—B_1)K_1$ = 0.00063
and K_1 = 0.0095

Table XVII.

25°. 0.2 N Sodium 1-phenyl-3-thiourazole + 0.066 N *n*-octyl iodide.

t.	*A.*	*A—x.*	*x.*	*B—x.*	*B.*	*(A—B)K.*
30	19.00	18.08	0.92	5.41	6.33	(0.00135)
240	19.00	15.70	3.30	3.03	6.33	0.000987
420	19.00	14.54	4.46	1.87	6.33	0.000983
1320	19.00	12.90	6.10	0.23	6.33	(0.000201)

Average, 0.000985
$(A_1—B_1)\ K_1$ = 0.00103
and K_1 = 0.16

Table XVIII.

25°. 0.1 N Sodium 1-phenyl-3-thiourazole + 0.033 N *n*-cetyl iodide.

t.	*A.*	*A—x.*	*x.*	*B—x.*	*B.*	*(A—B)K.*
120	9.50	9.37	0.13	3.036	3.166	0.0000193
240	9.50	9.27	0.23	2.936	3.166	0.0000508
480	9.50	9.06	0.44	2.726	3.166	0.0000718
1500	9.50	9.02	0.48	2.680	3.166	0.0000259

Average, 0 0000419
$(A_1—B_1)\ K_1$ = 0.0000441
and K_1 = 0.00132

Table XIX.

25°. 0.1 N Sodium 1-phenyl-3-thiourazole + 0.05 N iso-amyl iodide.

t.	*A.*	*A*—*x.*	*x.*	*B*—*x.*	*B.*	(*A*—*B*)*K.*
120	9.50	7.32	2.18	2.57	4.75	0.00128
240	9.50	6.44	3.06	1.69	4.75	0.00117
480	9.50	5.67	3.83	0.92	4.75	0.00102
1500	9.50	4.84	4.66	0.09	4.75	0.000953

Average, 0.0011

$(A_1—B_1)\ K_1 = 0.00116$

and $K_1 = 0.046$

Table XX.

25°. 0.2 N Sodium 1-phenyl-3-thiourazole + 0.2 N ethyl bromide.

t.	*A.*	*A*—*x.*	*x.*	*AK.*
30	19.22	14.28	4.94	0.01153
60	19.22	11.60	7.62	0.01095
120	19.22	8.10	11.12	0.01144
240	19.22	5.24	13.98	0.01111

Average, 0.01126

$A_1K_1 = 0.0117$ and $K_1 = 0.117$

15 mols. NaBr (1.5445 grams) added.

120	19.22	9.30	9.92	0.00888

Table XXI.

25°. 0.2 N Sodium 1-phenyl-3-thiourazole + 0.2 N *n*-propyl bromide.

t.	*A.*	*A*—*x.*	*x.*	*AK.*
30	19.22	15.52	3.70	0.00761
60	19.22	13.48	5.74	0.00709
120	19.22	10.30	8.92	0.00721
240	19.22	6.89	12.33	0.00745

Average, 0.00734

$A_1K_1 = 0.00764$ and $K_1 = 0.076$

Table XXII.

25°. 0.2 N Sodium 1-phenyl-3-thiourazole + 0.2 N isopropyl bromide.

t.	*A.*	*A—x.*	*x.*	*AK.*
30	19.22	18.68	0.54	(0.000963)
120	19.22	17.84	1.38	0.000644
240	19.22	16.82	2.40	0.000594
420	19.22	15.52	3 70	0.000568

Average, 0.000602

$A_1K_1 = 0.000626$ and $K_1 = 0.0063$

Table XXIII.

25°. 0.2 N Sodium 1-phenyl-3-thiourazole + 0.2 N *n*-butyl bromide.

t.	*A.*	*A—x.*	*x.*	*AK.*
60	19.10	13.22	5.88	0.00741
120	19.10	10.07	9.03	0.00747
'240	19.10	7.10	12.00	0.00704
360	19.10	5.50	13.60	0.00687
480	19.10	4.53	14.57	0.00670

Average, 0.0071

$A_1K_1 = 0.00743$ and $K_1 = 0.074$

Table XXIV.

25°. 0.2 N Sodium 1-phenyl-3-thiourazole + 0.2 N isobutyl bromide.

t.	*A.*	*A—x.*	*x.*	*AK.*
120	19.10	17.50	1.60	0.000761
240	19.10	16.40	2.70	0.000687
480	19.10	15.31	3.79	0.000516
660	19.10	14.52	4.59	0.000480

Average, 0.000611

$A_1K_1 = 0.000640$ and $K_1 = 0.0064$

Table XXV.

25°. 0.2 N Sodium 1-phenyl-3-thiourazole + 0.2 N ter. butyl bromide.

t.	*A.*	*A*—*x.*	*x.*	*AK.*
120	19.10	18.80	0.30	0.000132
240	19.10	18.70	0.80	0.000182
480	19.10	18.63	0.47	0.0000525
660	19.10	18.45	0.65	0.0000534

Average, 0.000105

$A_1K_1 = 0.000110$ and $K_1 = 0.0011$

Table XXVI.

25°. 0.2 N Sodium 1-phenyl-3-thiourazole + 0.2 N isoamyl bromide.

t.	*A.*	*A*—*x.*	*x.*	*AK.*
30	19.22	17.43	1.79	0.00342
70	19.22	15.46	3.76	0.00347
120	19.22	13.74	5.48	0.00333
240	19.22	10.54	8.68	0.00343

Average, 0.00342

$A_1K_1 = 0.00356$ and $K_1 = 0.0356$

Table XXVII.

25°. 0.2 N Sodium 1-phenyl-3-thiourazole + 0.2 N *n*-propyl chloride.

t.	*A.*	*A*—*x.*	*x.*	*AK.*
60	18.88	18.58	0.30	(0.000269)
240	18.88	18.30	0.58	0.000132
660	18.88	17.45	1.43	0.000128
1440	18.88	16.30	2.58	0.000110

Average, 0.00012

$A_1K_1 = 0.00013$ and $K_1 = 0.0013$

15 mols. NaCl (0.8769 gram) added.

660	18.88	17.75	1.13	0.0000965

Table XXVIII.

25°. 0.2 N Sodium 1-phenyl-3-thiourazole + 0.2 N isopropyl chloride.

t.	*A.*	*A—x.*	*x.*	*AK.*
120	18.88	18.58	0.30	0.000134
480	18.88	18.40	0.48	0.0000543
720	18.88	18.40	0.48	0.0000362
1440	18.88	18.33	0.55	(0.0000206)
			Average,	0.0000748

$A_1K_1 = 0.00008$ and $K_1 = 0.0008$

Table XXIX.

25°. 0.2 N Sodium 1-phenyl-3-thiourazole + 0.2 N *n*-butyl chloride.

t.	*A.*	*A—x.*	*x.*	*AK.*
120	18.58	17.48	1.10	0.000524
240	18.58	17.39	1.19	0.000283
480	18.58	16.87	1.71	0.000211
1440	18.58	15.74	2.84	(0.000125)
			Average,	0.000340

$A_1K_1 = 0.000365$ and $K_1 = 0.0036$

Table XXX.

25°. 0.2 N Sodium 1-phenyl-3-thiourazole + 0.2 N isobutyl chloride.

t.	*A.*	*A—x.*	*x.*	*AK.*
120	18.88	18.66	0.22	(0.0000982)
440	18.88	18.58	0.30	0.0000336
720	18.88	18.58	0.30	0.0000224
1440	18.88	18.15	0.73	0.0000279
			Average,	0.000028

$A_1K_1 = 0.0000295$ and $K_1 = 0.00029$

Table XXXI.

25°. 0.2 N Sodium 1-phenyl-3-thiourazole + 0.2 N tertiary butyl chloride.

t	*A.*	*A*—*x.*	*x.*	*AK.*
120	18.88	18.27	0.61	(0.000277)
480	18.88	18.29	0.59	0.0000672
720	18.88	18.19	0.68	0.0000591
1440	18.88	18.06	0.82	0.0000308

Average, 0.000052

$A_1K_1 = 0.000055$ and $K_1 = 0.00055$

Table XXXII.

25°. 0.2 N Sodium 1-phenyl-3-thiourazole + 0.2 N isoamyl chloride.

t.	*A.*	*A*—*x.*	*x.*	*AK.*
60	18.88	18.60	0.28	(0.000250)
240	18.88	18.49	0.39	0.0000870
660	18.88	18.10	0.78	0.0000653
1440	18.88	17.40	1.48	(0.0000591)

Average, 0.000071

$A_1K_1 = 0.000075$ and $K_1 = 0.00075$

Table XXXIII.

50°. 0.05 N 1-Phenyl-3-thiourazole + 0.05 N ethyl iodide.

t.	*A.*	*A*—*x.*	*x.*	*AK.*	K_1.
5	4.90	4.11	0.79	0.0384	
				$A_1K_1=0.0392$	1.568
10	4.90	3.57	1.33	0.0373	
				$A_1K_1=0.0380$	1.520
15	4.90	3.18	1.72	0.0360	
				$A_1K_1=0.0367$	1.468
31	4.90	2.46	2.44	0.0319	
				$A_1K_1=0.0325$	1.300
60	4.90	1.88	3.02	0.0268	
				$A_1K_1=0.0273$	1.096
120	4.90	1.29	3.61	0.0234	
				$A_1K_1=0.0238$	0.952
240	4.90	0.66	4.24	0.0268	
				$A_1K_1=0.0273$	1.096
5 mols. HCl. (sp. gr. 1.20)(0.388 cc.) added.					
60	4.71	3.54	1.17	0.0055	

Table XXXIV.

50°. 0.05 N 1-Phenyl-3-thiourazole + 0.05 N methyl iodide.

t.	*A.*	*A*—*x.*	*x.*	*AK.*	K_1.
3	4.90	2.05	2.85	0.463	
			A_1K_1=	0.472	18.88
5	4.90	1.40	3.50	0.500	
			A_1K_1=	0.510	20.40
10	4.90	0.90	4.20	0.444	
			A_1K_1=	0.453	18.12
15	4.90	0.75	4.15	0.369	
			A_1K_1=	0.377	15.04
30	4.90	0.67	4.23	0.210	
			A_1K_1=	0.214	8.56
60	4.90	0.93	3.97	0.0711	
			A_1K_1=	0.0725	2.90

Table XXXV.

25°. 0.05 N 1-Phenyl-3-thiourazole + 0.05 N ethyl iodide.

t.	*A.*	*A*—*x.*	*x.*	*AK.*
60	4.71	3.69	1.02	0.00460
150	4.71	2.83	1.88	0.00443
			Average,	0.00451

A_1K_1 = 0.00479 and K_1 = 0.192

Table XXXVI.

Change of 1-Phenyl-3-thiourazole into the Disulphide.

50°. 0.05 N 1-Phenyl-3-thiourazole in 50 per cent alcohol.

t.	*A.*	*A*—*x.*	*x.*	*AK.*
61	4.90	4.87	0.03	0.000101
150	4.90	4.82	0.08	0.000110
214	4.90	4.78	0.12	0.000116
300	4.90	4.68	0.22	0.0001085
390	4.90	4.64	0.26	0.000143
			Average,	0.00012

A_1K_1 = 0.00012 and K_1 = 0.0024

Table XXXVII.

50°. 0.2 N Sodium 1-phenyl-3-thiourazole + 0.2 N sodium chloracetate in water solution.

t.	*A.*	*A—x.*	*x.*	*AK.*
15	18.50	15.60	2.90	(0.0124)
30	18.50	12.00	6.50	0.0180
60	18.50	8.97	9.53	0.0177
120	18.50	6.14	12.36	0.0168
			Average,	0.0175

$A_1K_1 = 0.0189$ and $K_1 = 0.189$

Table XXXVIII.

50°. 0.2 N Sodium 1-phenyl-3-thiourazole + 0.2 N sodium chloracetate in 50 per cent alcohol.

t.	*A.*	*A—x.*	*x.*	*AK.*
15	18.71	15.30	3.41	0.0148
30	18.71	13.13	5.58	0.0141
60	18.71	10.39	8.32	0.0133
			Average,	0.0141

$A_1K_1 = 0.015$ and $K_1 = 0.15$

Table XXXIX.

25°. 0.2 N Sodium thioacetate + 0.2 N ethyl iodide.

t.	*A.*	*A—x.*	*x.*	*AK.*
15	13.78	10.20	3.78	0.0252
30	13.78	7.41	6.37	0.0286
60	13.78	5.02	8.76	0.0290
120	13.78	2.54	11.24	(0.0368)
240	13.78	0.90	12.88	(0.0596)
			Average,	0.027

$A_1K_1 = 0.040$ and $K_1 = 0.40$

Table XL.

50°. N Potassium hydroxide + N ethyl iodide.

t.	*A.*	*A—x.*	*x.*	*AK.*
15	10.00	8.47	1.53	0.0120
30	10.00	7.49	2.51	0.0111
60	10.00	6.18	3.82	0.0103
120	10.00	4.37	5.63	0.0107
			Average,	0.011

$K_1 = 0.022$

After the normal ethyl iodide in absolute alcohol had stood for forty-eight hours, 10 cc. were titrated with 0.1 N potassium hydroxide. 4.56 cc. were required. This showed that the ethyl iodide may be decomposed in the water and alcohol and accounts for the decrease in the velocity constant in the above table. See also Table XLIV.

Table XLI.

50°. N Potassium hydroxide and N ethyl iodide with 5 mols. KI (8.30 grams) added.

t.	*A.*	*A*—*x.*	*x.*	*AK.*
15	10.00	8.99	1.01	0.00741
30	10.00	8.37	1.63	0.00648
60	10.00	7.50	2.50	0.00555
120	10.00	6.19	3.81	0.00512
			Average,	0.00614
			K_1 =	0.01228

Table XLII.

50°. N Potassium hydroxide + N methyl iodide.

	A.	*A*—*x.*	*x.*	*AK.*
4	10.00	7.05	2.95	0.104
8	10.00	5.69	4.31	0.0947
15	10.00	4.39	5.61	0.0852
32	10.00	2.99	7.01	0.0733
			Average,	0.0893
			K_1 =	0.1786

Table XLIII.

50°. N Potassium hydroxide and N methyl iodide with 5 mols. KI (8.30 grams) added.

t.	*A.*	*A*—*x.*	*x.*	*AK.*
4	10.00	8.40	1.60	0.0476
8	10.00	7.19	2.81	0.0382
15	10.00	5.91	4.09	0.0461
32	10.00	4.50	5.50	0.0381
			Average,	0.0425
			K_1 =	0.085

Table XLIV.

50°. Hydrolysis 0.5 N methyl iodide in 50 per cent alcohol.

t.	A.	$A-x$.	$K=\frac{1}{t}\log\frac{A}{A-x}$.
4	9.83	9.81	0.00022
9	9.83	9.77	0.00029
32	9.87	9.66	0.00024
90	9.87	9.42	0.00020
180	9.83	9.30	(0.00012)
240	9.83	8.67	0.00022
1440	9.83	6.51	(0.00012)
		Average,	0.00023

Table XLV.

The reaction between sodium phenyl-3-thiourazole and ethyl iodide was followed by means of conductivity measurements. Special experiments showed that the conductivity of the sodium urazole was not changed by the addition of the ethyl iodide. This shows that the ethyl iodide does not unite appreciably with the sodium or urazole ions.

25°. 0.2 N Sodium 1-phenyl-3-thiourazole + 0.2 N C_2H_5I in 50 per cent ethyl alcohol.

μv.	t.	Resistance.	a.	b.	AK.
15.48	0.0	102	54.70	45.30	....
16.52	2.9	102	56.30	43.70	0.0530
17.42	6.0	102	57.60	42.40	0.0728
17.90	11.3	60	45.10	54.90	0.0539
18.80	17.3	60	46.30	53.76	0.0620
19.95	30.2	60	47.80	52.20	0.0972
21.02	56.2	60	49.10	50.90	0.114
21.46	77.5	60	49.60	50.40	0.155
21.88	....	60	50.10	49.90	

It is evident that the method must be studied further in order to secure better constants. The conductivity data prove conclusively that only a very small amount of alkyl halide can be combined at any moment with the sodium or urazole ions.

Table XLVI.

25°. 0.1 N Sodium 1-phenyl-3-thiourazole + 0.1 N C_2H_5I in 50 per cent ethyl alcohol.

μ_v.	*t.*	Resistance.	*a.*	*b.*	*AK.*
17.62	0.0	140	48.10	51.90	.....
18.79	4.8	140	49.70	50.30	0.0309
20.52	13.3	140	51.90	48.10	0.0356
21.88	24.5	140	53.50	46.50	0.0366
22.87	31.6	140	54.60	45.40	0.0442
23.72	44.6	140	55.50	44.50	0.0470
24.30	59.6	140	56.10	43.90	0.0482
24.78	77.8	100	48.20	51.80	0.0496
26.63	....	100	50.00	50.00	.....

The method must be improved by further work.

Conclusions.

1. Work on the reactions of alkyl halides with urazoles, hydroxides, carbonates, thioacetates, etc., seems to prove that the alkyl halide reacts with the anion of the urazole, hydroxide, etc., according to the expression

$$C_2H_5I + \overline{OH} \rightarrow C_2H_5OH + \overline{I},$$

or

$$\frac{dx}{dt} = K_{trans} \times C_{ethyl\ iodide} \times C_{OH.}$$

2. The alkyl halides do not seem to form alkyl derivatives of other substances through the intermediate dissociation into alkyl and halide ions, as Bruyn and Steger assumed:

$$KOH + C_2H_5I \rightleftarrows \overset{+}{K} + \overline{OH} + \overset{+}{C_2H_5} + \overline{I} \rightarrow C_2H_5OH + \overset{+}{K} + \overline{I}.$$

3. The experimental evidence is not in harmony with the view of Nef that alkyl halides react with compounds because the alkyl halide first dissociates into the corresponding halogen acid and an unsaturated methylene or olefine derivative, which then reacts with another substance:

$$C_2H_5I + \overset{+}{K} + \overline{OC_2H_5} \rightleftarrows$$

$$CH_3CH \rightleftarrows + \overset{+}{H} + \overline{I} + \overset{+}{K} + \overline{OC_2H_5} \rightarrow$$

$$CH_3CH \rightleftarrows + HOC_2H_5 + \overset{+}{K} + \overline{I} \rightarrow$$

$$CH_3CH_2—O—C_2H_5 + \overset{+}{K} + \overline{I}.$$

4. The alkyl halides do not seem to react with salts by first uniting with the cation and forming a complex cation which then reacts with the anion, as Euler assumed:

$$C_2H_5I + \overset{+}{K} + \overset{-}{OH} \rightleftharpoons C_2H_5I.\overset{+}{K} + \overset{-}{OH} \rightarrow C_2H_5OH + \overset{+}{K} + \overset{-}{I}.$$

5. The alkyl halide seems to react as a neutral molecule with the anion of the substance which is alkylated, perhaps forming an unstable intermediate complex anion.

6. The alkyl iodides are more reactive towards the urazoles than are the alkyl bromides, and these in turn are more reactive than the alkyl chlorides. The primary alkyl halides are more reactive towards the urazoles than are the secondary alkyl halides, and these are more reactive than the tertiary alkyl halides. The so-called space interference seems to be effective in these reactions.

BIOGRAPHICAL.

Guy H. Shadinger was born in Sibley County, Minnesota, August 24, 1877. He received his early education in the public schools of Glencoe, Minnesota, and in Stevens Seminary at the same place. In 1896 he entered Hamline University, St. Paul, Minnesota, and graduated with the Ph.B. degree in 1900. He studied Botany at the University of Minnesota during the summer of 1900.

He has taught as follows: Mathematics and Chemistry, Hutchinson High School, Minnesota, 1900–1901; Zoology and Chemistry, Red Wing High School, Minnesota, 1901–1904.

In October, 1904, he entered the Johns Hopkins University as a graduate student in chemistry, his subordinate subjects being Physical Chemistry and Mathematics. He acted as laboratory assistant to Dr. Gilpin during the year 1905–1906.